Iron and Steel ENGINEER

ENGINEERING SERVICE TO THE IRON AND STEEL INDUSTRY SINCE 1907

OCTOBER, 1950

TECHNOLOGY DEPT.

TABLE OF CONTENTS, Page 35

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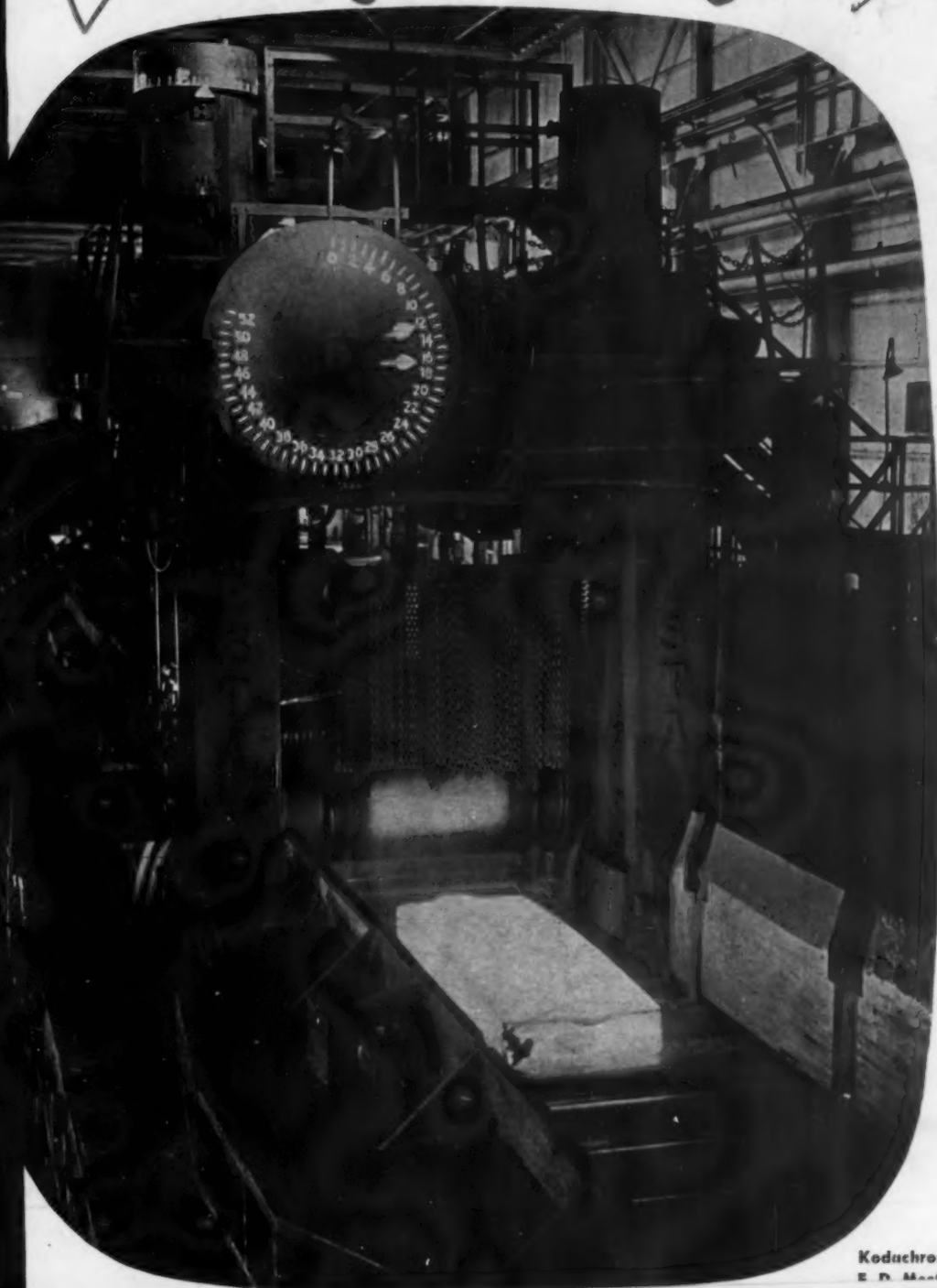
Modern Reversing Slabbing-Blooming Mills

Designed and Built by

MESTA

MACHINE COMPANY, PITTSBURGH, PA.



Kodachrome by

Carnegie-Illinois Temper Pass Mill REBUILT

-Speeds now to 2500 fpm

Behind this feat is the engineering know-how of Cutler-Hammer, Elliott, and Reliance

Part of a modernization program instituted at the Carnegie-Illinois Irvin Works was the complete rebuilding of the No. 3 sheet temper pass mill. This now-modern mill processes coils of steel sheet up to 50 inches in width, 72 inches in diameter, and 50,000 lbs. in weight, at a speed range of 250 to 2500 feet per minute, with 3750 fpm a possibility in the future. Control of this mill is such that the operator can maintain tension at any degree—the requirement most vital to uniform sheet texture and quality—during "stall", acceleration, normal operation at any selected speed and especially during deceleration. Cutler-Hammer furnished the control engineering behind this outstanding achievement . . . as has been so often the case in events that have written steel mill history . . . CUTLER-HAMMER, Inc., 1269 St. Paul Ave., Milwaukee 1, Wisconsin. *Associate:* Canadian Cutler-Hammer, Ltd., Toronto, Ontario.

(A) 2500 fpm is the speed of the strip passing through this new mill.

(B) Two Cutler-Hammer Control stands provide these operators with control of all operations of the mill.

(C) Cutler-Hammer Control Panel for D.C. Main Mill Drive.

(D) Cutler-Hammer D.C. Auxiliary Control and A.C. Unitrol cubicles.

Features of the New Temper Pass Mill Drive

All operations performed from operator's cabinet at each end of mill. Threading strip through mill done in minimum time. Strip tension between mill and reels then regulated to desired degree by means of Reliance VSA current regulating exciters. By proper adjustment of compensation for IR drop, friction, windage, and strip speed, tension may be held constant or tapered as required for uniform quality of processed strip. Change in reel motor current and thus tension, is translated to VSA regulators which immediately modify reel motor fields to re-establish the tension. Sudden transient requirements of wider current modification are also translated to VSA voltage regulators. Reel generators immediately respond to help re-establish desired current. Required change in current and torque when accelerating and decelerating is measured by a WR^2 compensating device which responds to rate of change in mill speed and thus insures proper compensation with any rate of acceleration.

IRON AND STEEL ENGINEER, published monthly by Association of Iron and Steel Engineers, 1010 Empire Bldg., entered as second class matter January 25, 1924 at Pittsburgh, Pennsylvania, under Act of Congress, March 3, 1879. $7.50 per year in United States and Canada, $10.00 foreign countries Volume 27, No. 10.

products

Seamless Tube Mills
Piercing Mills
Plug Mills
Reelers
Sizing Mills
Reducing Mills
Continuous Butt Weld Pipe Mills
Continuous Seamless Tube Rolling Mills
Levellers
Shears
Slitters
Tension Reels
Upcoilers
Pilers
Side Trimmers
Stretcher Levellers
Pay-off Reels
Down Coilers
Coil Breakers
Side Trimming Lines
Slitting Lines
Scrubbing and Drying Lines
Continuous Strip Galvanizing Lines
Sheet Galvanizing Lines
Continuous Strip Long Terne Lines
Continuous Electrolytic Tinning Lines
Hot Dip Tinning Equipment
Cutting-off Machines
Continuous Pipe Galvanizing Equipment
Mill Tables
Cooling Beds
Drawbenches
Bar Turning Pointers
Hydraulic Squeeze Pointers
Wire Pointers
Bending Machines
Wire Drawing Machines
Rolling Mill Rolls

Around the Globe with AETNA-STANDARD

Wherever around the globe your company may be contemplating expansion, or building for manufacture or processing of ferrous or non-ferrous products, Aetna-Standard can assist.

Aetna-Standard has a world-wide export organization to serve your particular interests in the United States, Canada and abroad. Like our plants in Ohio and Pennsylvania, we specialize abroad in pipe and tube mills, drawbenches, flat rolled equipment, wire drawing machines and other products.

In the event your company contemplates any industrial programs abroad, Aetna-Standard can be of assistance. Write direct to us in Youngstown, Ohio, U.S.A., if your country is not listed below.

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THE AETNA-STANDARD ENGINEERING COMPANY · YOUNGSTOWN, OHIO

Plants in Warren, Ohio · Ellwood City, Pennsylvania

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Head Wrightson Machine Company, Ltd., Middlesbrough, England—Great Britain, Finland, Sweden, Norway, Denmark, Union of South Africa, Northern and Southern Rhodesia.

Aetna-Standard Engineering Company, Ltd., Toronto, Ontario, Canada.

M. Castellvi, Inc., New York, N. Y.—Mexico, Central and South America.

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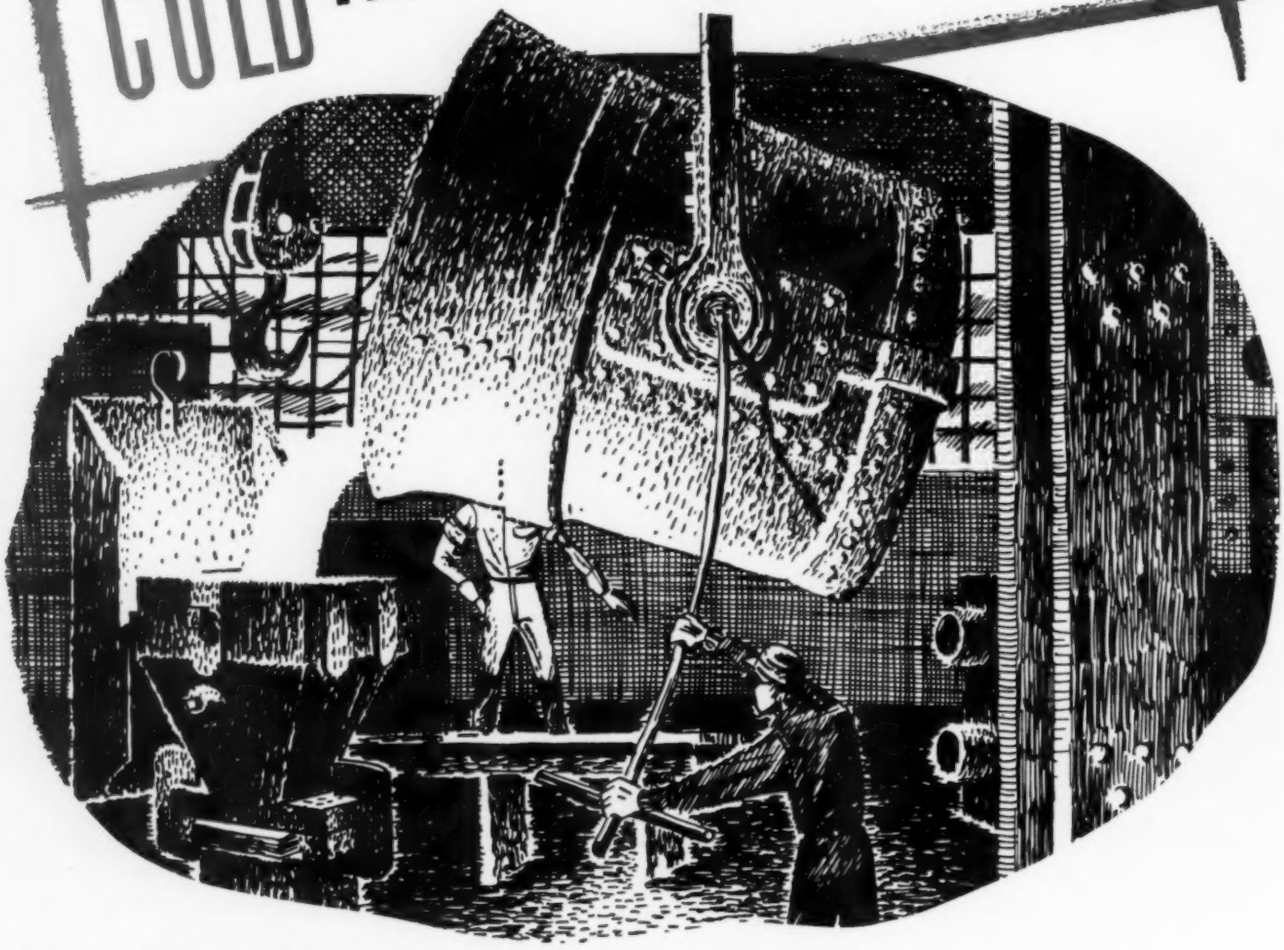
Aetna-Japan Company, Ltd., Tokyo, Japan—Japan.

Hale & Kullgren, Inc., Akron, Ohio—Representative for the Rubber Industry.

Designers and Builders to the Ferrous, Non-Ferrous, Leather and Rubber Industries

COLD FACTS ON A HOT SUBJECT



Pouring a roll is no "cinch", but it is the most important factor in the successful performance of the finished roll. In that important step, all the metallurgical knowledge and practical experience of the roll maker must be put to work to assure the right hardness, chill depth and heat resistance.

Here at National, we have been pouring rolls for more than forty years and this experience plus our metallurgical staff is reflected in the sound, long-wearing iron rolls that are giving good service throughout the industry.

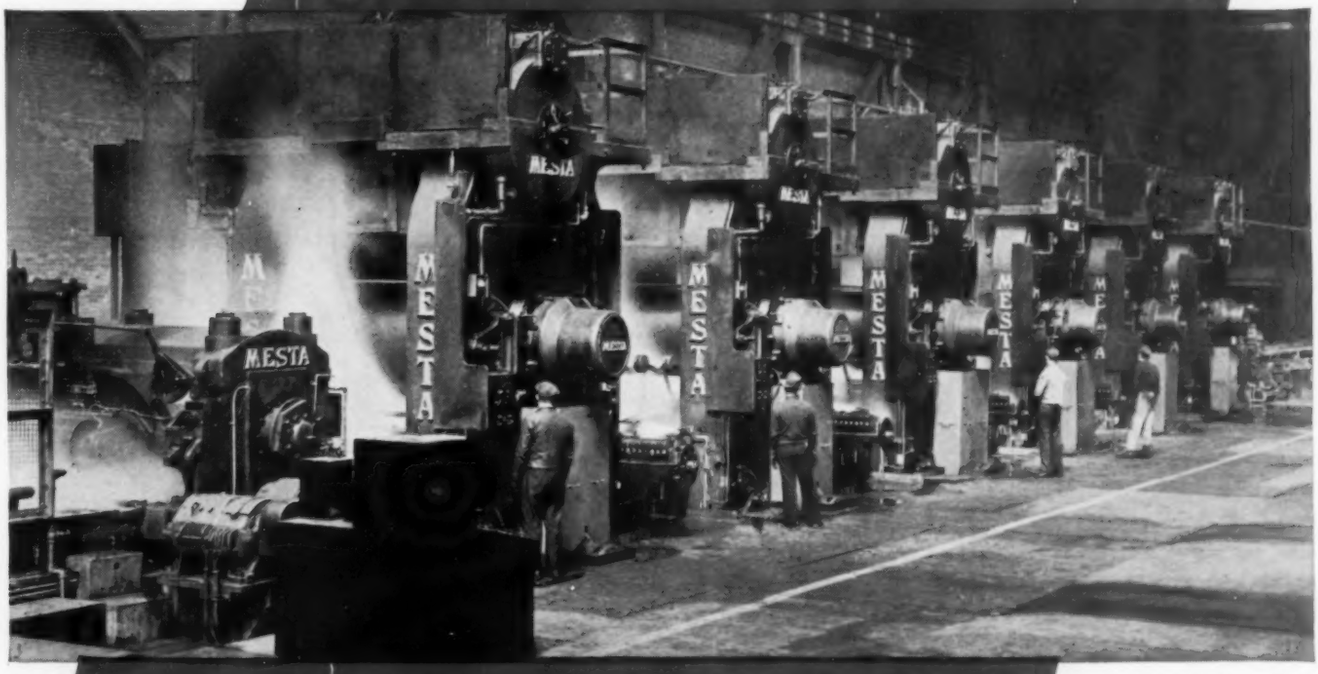
NATIONAL ROLLS

THE NATIONAL ROLL & FOUNDRY CO.

AVONMORE, PENNSYLVANIA

SPECIALISTS IN IRON AND ALLOY IRON ROLLS AND CASTINGS

TRIPLE PROTECTION FOR ROLL NECKS



Mesta Machine Photo

Guard against friction, heavy loads and high temperatures by using TEXACO REGAL OILS

With *Texaco Regal Oils* in your circulating systems, your oil film roll necks will always have super-tough lubricating films to roll on. These turbine-grade oils keep oil lines clear, permitting clean, cooling lubricant to flow constantly to the bearings. This means trouble-free performance, uninterrupted production, longer bearing life, lower maintenance costs.

Texaco Regal Oils embody high resistance to oxidation, emulsification and sludging. Their friction-fighting films stand up under heavy loads and high temperatures. Operators everywhere get better results with *Texaco Regal Oils.*

Over on the drive side, protect your heavy-duty enclosed gears by using *Texaco Meropa Lubricants* — noted for their high load-carrying capacity and high resistance to foaming and oxidation. Both gears and bearings will last longer.

There are many ways in which a Texaco Lubrication Engineer can help you increase efficiency and reduce costs. Just call the nearest of the more than 2,000 Texaco Wholesale Distributing Plants in the 48 States, or write:

The Texas Company, 135 East 42nd Street, New York 17, N. Y.

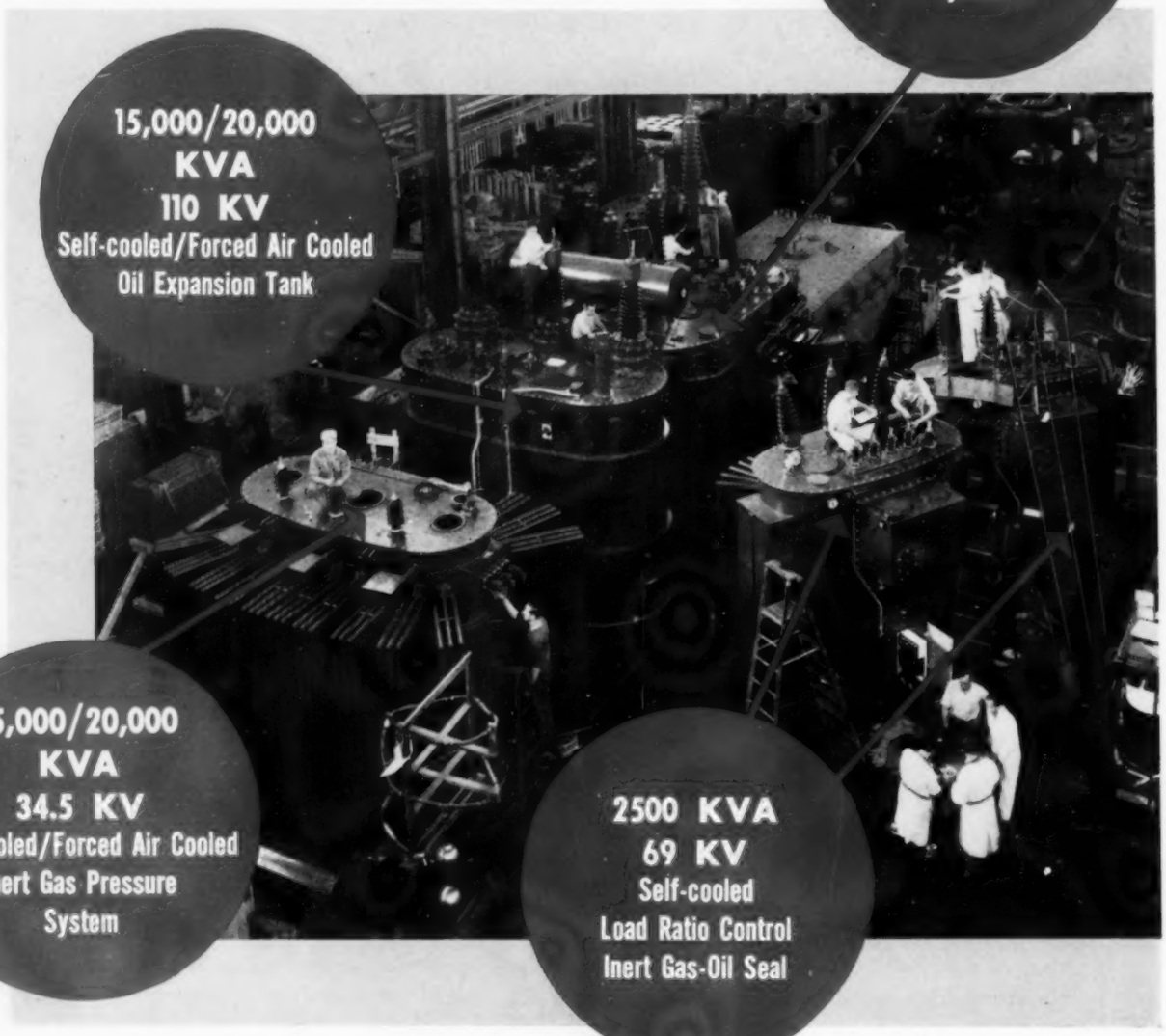
VISIT THE TEXACO EXHIBIT AT THE METALS SHOW • BOOTH 1906 • CHICAGO, OCTOBER 23-27

TEXACO REG T M

TEXACO Regal Oils
(HEAVY CIRCULATING OILS)

TUNE IN . . . TEXACO STAR THEATER starring MILTON BERLE on television every Tuesday night. See newspaper for time and station.

POWER TRANSFORMERS assembled HERE..



This section of the Pennsylvania plant is known as the Finishing Department. All Power transformers stop here for final assembly and finishing before going to the Test Department.

The group of transformers pictured is representative of the types of Power transformers designed and manufactured by Pennsylvania.

Transformers in this group range from 2500 Kva to 30,000 Kva. Some are equipped with no load tap changers; others with underload tap changers.

Many types of cooling methods are represented — self-cooling, forced air cooling, and forced oil cooling.

Methods of oil preservation include Inert Gas-Oil Seal, Oil Expansion Tank, and Inert Gas Pressure Systems.

Other Power transformers regularly built by Pennsylvania have ratings up to 100,000 Kva and voltages up to and including 230 Kv.

Pennsylvania TRANSFORMERS

Pennsylvania TRANSFORMER COMPANY

CANONSBURG, PENNSYLVANIA • *Greater Pittsburgh District*

OVER 90 YEARS LEWIS OF ROLL MAKING

MOLYBDENUM CHILLED IRON ROLLS

PLAIN CHILLED IRON ROLLS

ATLAS and ATLAS "B" ROLLS

CLIMAX and AJAX ROLLS

"X" and "XA" ROLLS

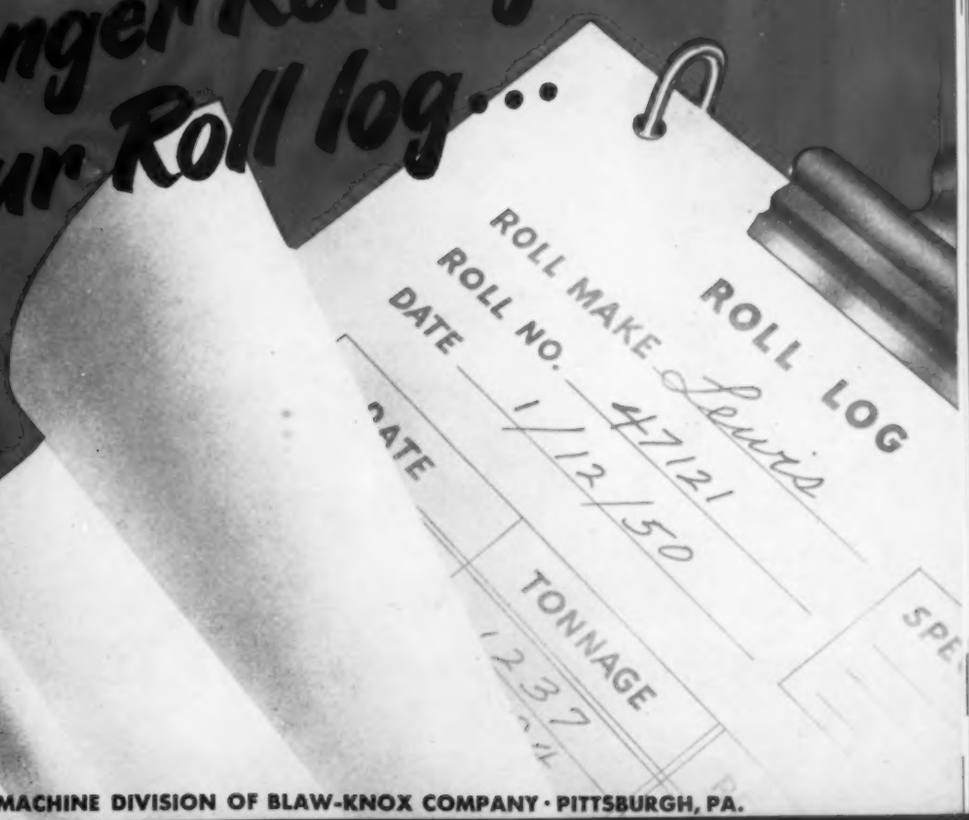
SUPERIOR "X" ROLLS

SPECIAL PROCESS ROLLS

SPECIAL TUBE MILL ROLL

AJAX DUPLEX ROLLS

Spell longer Rolling life in your Roll log...



MANUFACTURERS OF
ROLLS AND ROLLING MILL MACHINERY
FOR THE IRON, STEEL AND
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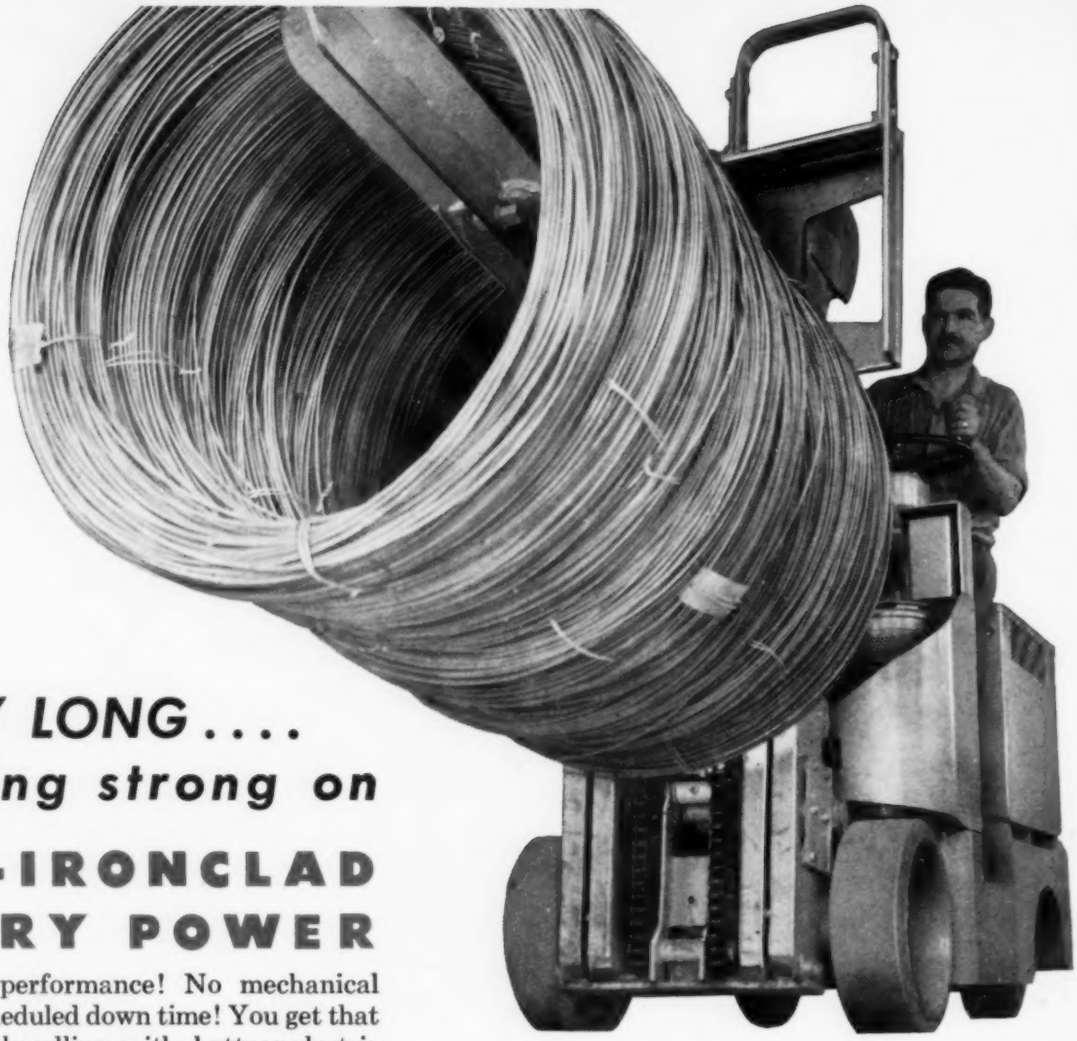
LEWIS FOUNDRY AND MACHINE DIVISION OF BLAW-KNOX COMPANY · PITTSBURGH, PA.



ALL DAY LONG . . . . still going strong on

EXIDE-IRONCLAD BATTERY POWER

Round-the-clock performance! No mechanical troubles! No unscheduled down time! You get that kind of materials-handling with battery-electric trucks and Exide-Ironclad Batteries. You also get:

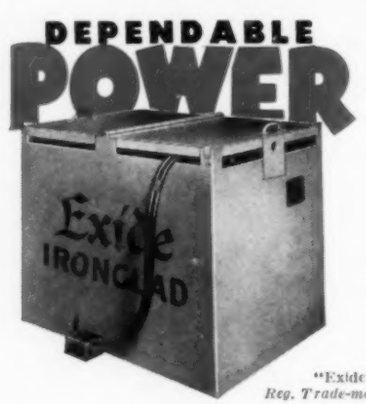
- instant surge of power to meet all demands in *start-stop, lift-and-shift* manipulations . . . plus finger-tip control for split-second handling, easy maneuvering, accurate spotting.
- uniform speed throughout shift, with trucks handling as much tonnage during last hour as during first.
- exceptionally long life—proved on more than 100,000 heavy-duty jobs.
- low operating costs—batteries are easy to keep charged for they absorb a very high percentage of charging current. Recharging costs as low as 2 cents per K.W.H. of battery capacity.
- low maintenance costs—no moving parts to get out of adjustment or break . . . easy to charge, change, add water, keep records of water additions, gravity and voltage . . . seldom costs more than 15 cents per shift to maintain.
- inherent safety—battery power provides quiet operation with less worker fatigue; no fire hazard, no contaminating fumes; no vibration to jar work in transit; no oil seepage on floors to create accident hazards.
- wide range of sizes for every make of battery-electric truck; compact construction permits standardization.

Combined, these and other Exide-Ironclad characteristics assure you dependable performance, day after day . . . for years.

Exide-Ironclad Batteries are the Best Power Buy . . . AT ANY PRICE

Write for more facts and FREE copy of Exide-Ironclad Topics. It contains latest developments in materials-handling . . . shows actual case histories.

THE ELECTRIC STORAGE BATTERY COMPANY
Philadelphia 32
Exide Batteries of Canada, Limited, Toronto



"Exide-Ironclad"
Reg. Trade-mark U.S. Pat. Off.

1888 . . . DEPENDABLE BATTERIES FOR 62 YEARS . . . 1950

POOLE

A COPY OF CATALOG GIVING FULL DESCRIPTION AND ENGINEERING DATA SENT UPON REQUEST.

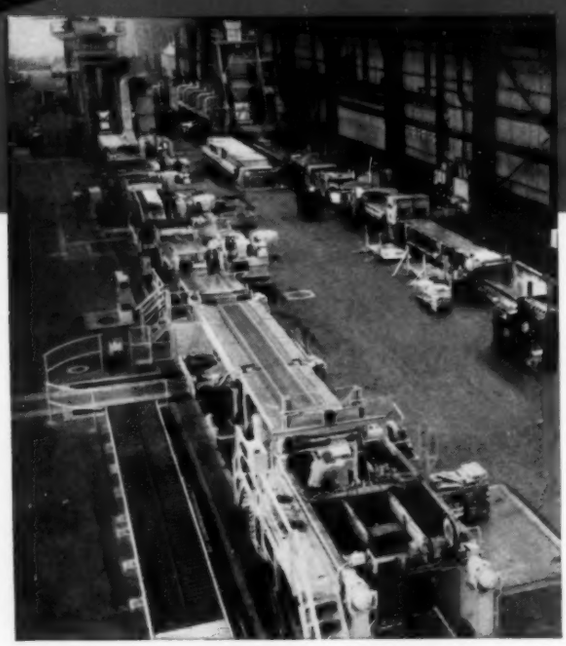
FLEXIBLE COUPLINGS

POOLE FOUNDRY & MACHINE COMPANY

WOODBERRY, BALTIMORE, MD.

G-E drive for 48" continuous annealing and galvanizing line -helps speed production of uniform-quality light-gage strip!

General Electric engineered drive and furnace handles .012 to .040 strip at speeds from 50 to 300 fpm, for output up to 10 tons per hour!



Co-ordinated G-E control in this line keeps output high, operating costs down, with features like these: 1) loop-filling-and-emptying control that permits maximum loop storage, protects against shutdowns; 2) automatic speed and tension controls minimize strip breakage and help maintain uniform product quality; 3) side-register control on re-coiler to maintain straight-edge coils; 4) welder control interlocked with line control to minimize welding time. Shown here in left foreground is delivery end of line.

To anneal and galvanize light-gage strip continuously, a large Pennsylvania steel mill recently installed a new galvanizing line complete with G-E drive and G-E electric furnace with protective atmosphere. Worked out co-operatively with Wean Engineering Co., Inc., the co-ordinated G-E drive makes possible these major advantages over former batch methods.

Higher rate of output—Galvanizing a given piece of steel now takes minutes, drastically reducing quantity of material in process.

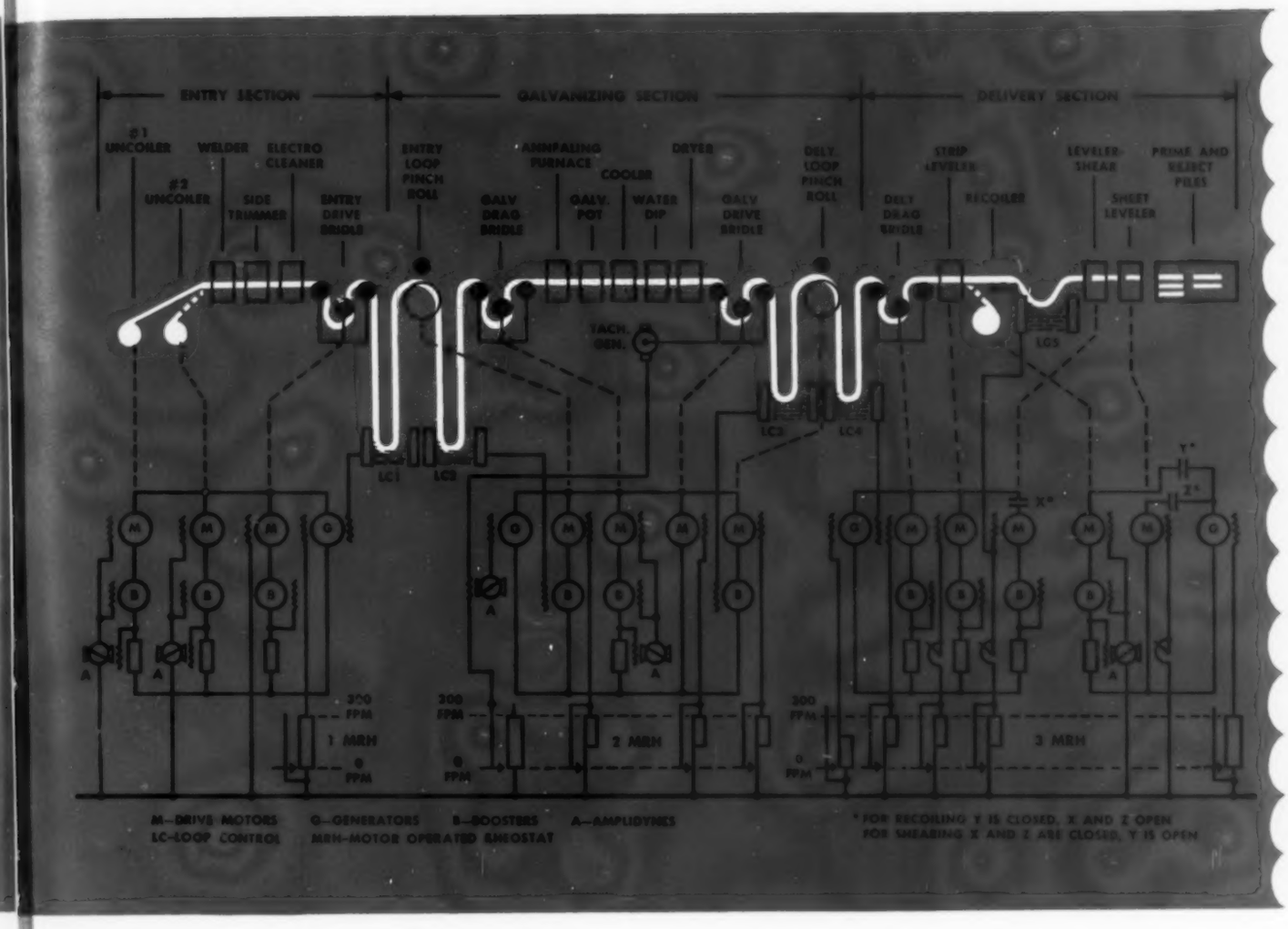
A more uniform product—Corrosion resistance, drawing qualities, zinc adherence, and appearance are all greatly improved.

Lower operating costs—Manpower is freed for other duties, rejects are fewer, fluxing is eliminated, and zinc consumption held to a minimum.

Here is further proof that, for help in meeting *your* needs for higher-speed, more accurately controlled drives, your best bet is to call in a G-E steel-mill specialist—early. *Apparatus Dept., General Electric Company, Schenectady 5, N. Y.*

GENERAL ELECTRIC

659-75



HERE'S HOW IT OPERATES

The drive for this continuous galvanizing line is divided into three sections which may be operated independently or in tandem. Amplidyne regulators maintain strip tension through each section and an amplidyne speed regulator holds strip speed constant through the galvanizing section. Looping pits provide strip storage to permit temporary shut-down of the entry section for welding, or of the delivery section for removing coils or stacks, without disturbing the continuous flow of strip through the galvanizing section.

The speed of each section is controlled by a motor-operated rheostat (1MRH, 2MRH, 3MRH). Approximate speed matching between sections is provided by automatic positioning of the motor-operated rheostats, and photoelectric loop controls (LC1, LC4) act on entry and delivery generator auxiliary fields to produce exact speed matching and maintain loop position.

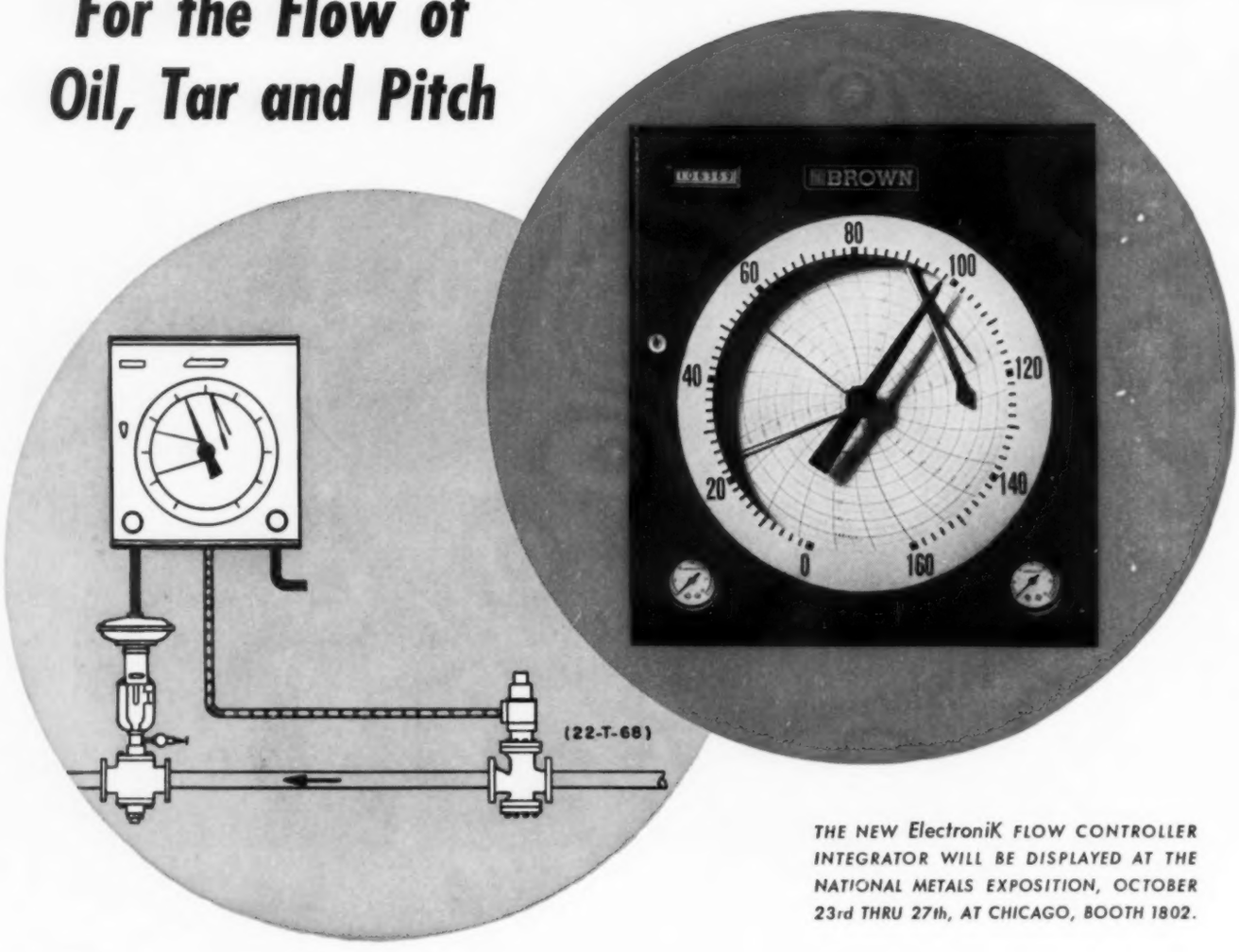
The entry and delivery sections automatically overspeed after a shutdown to restore normal loop positions as quickly as possible. When either end section is shut down, the corresponding loop pinch roll is automatically operated at half of galvanizing section speed, thereby causing both halves of the storage loop to pay out or fill evenly.

This condensed diagram, including only major drives, does not show 13 additional minor drives connected to the adjustable-voltage systems.

another example of
GENERAL ELECTRIC
drive engineering
at work!

NOW! *ElectroniK* Air-O-Line CONTROL

For the Flow of Oil, Tar and Pitch



THE NEW ElectroniK FLOW CONTROLLER INTEGRATOR WILL BE DISPLAYED AT THE NATIONAL METALS EXPOSITION, OCTOBER 23rd THRU 27th, AT CHICAGO, BOOTH 1802.

THE Brown Area Electric Flow Meter, service proven in thousands of viscous fluid metering applications, can now be combined with the famous *ElectroniK* Controller . . . reaching a new high level of precision performance in flow instrumentation.

Illustrated in the diagram is the *ElectroniK* Potentiometer, with its unusual sensitivity and accuracy . . . (1) teaming up with a new, simple electronic integrator . . . (2) utilizing the high-precision *Air-O-Line* unit to actuate a Honeywell diaphragm valve for pin-point control . . . and (3) providing a permanent record and large indicating scale . . . complete in a single unit. Each unit and component contributes to a full capitalization of the unusual operating advantages of the Brown Area Type Meter.

For a detailed discussion of the application of this system to the control of your viscous fluids, call in your local Honeywell engineer . . . he is as near as your phone.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, 4464 Wayne Ave., Philadelphia 44, Pa. Offices in more than 80 principal cities of the United States, Canada and throughout the world.

FOR METAL PRODUCING

MINNEAPOLIS **Honeywell**

BROWN INSTRUMENTS

How to simplify your piping jobs ...Standardize on the CRANE line

ECONOMICAL VALVES FOR LOW PRESSURES

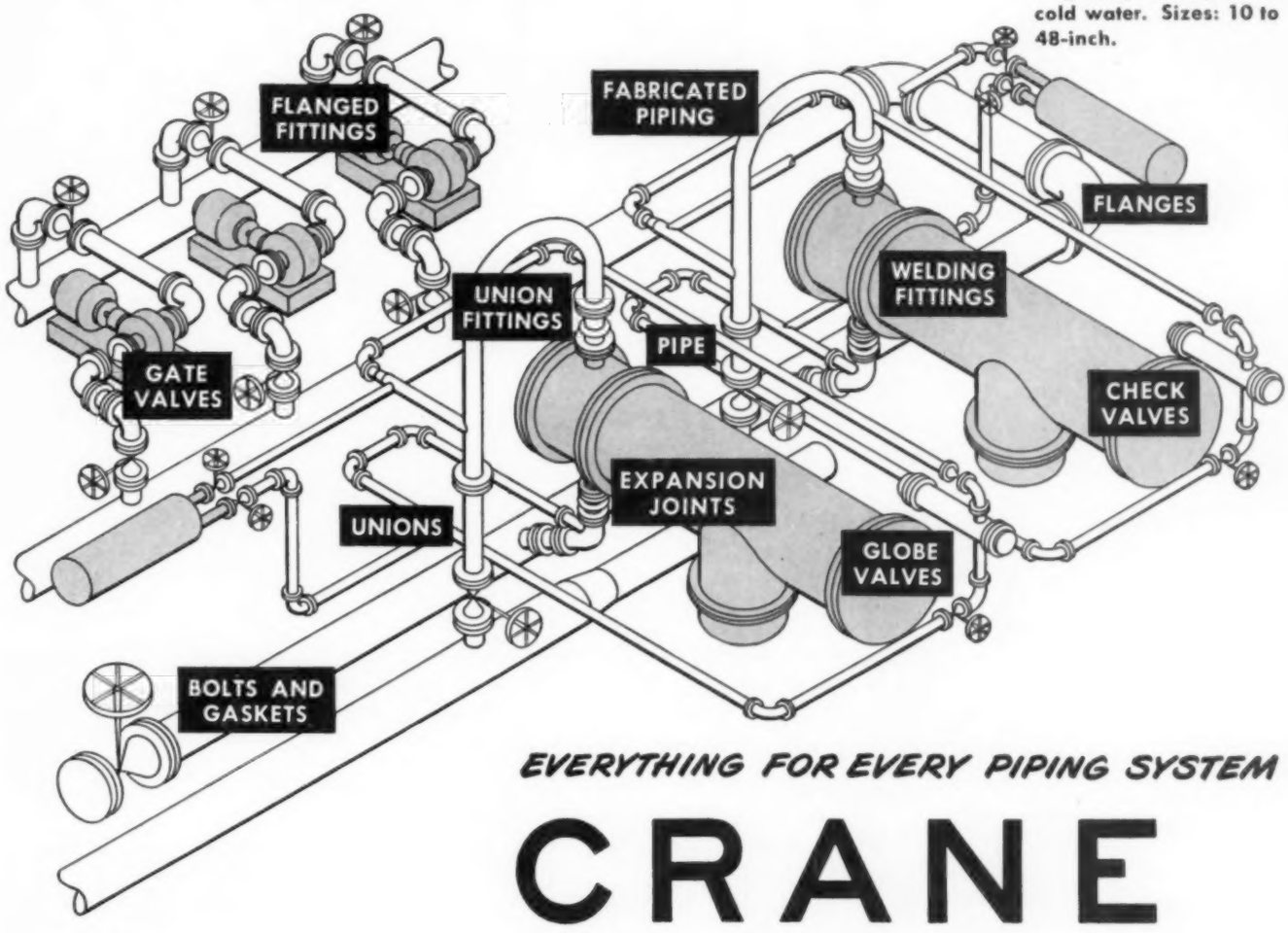
Keep Crane 25-Pound Iron Body Double Disc Gates in mind for services that don't require the usual 125-Pound valves. Rated at 25 Pounds Steam or Gas, and up to 50 Pounds Water, depending on size, they give superior service in a wide variety of applications. Use them inside or out; their oval-shaped body and bonnet have ample reserve strength under line stresses. Short and compact, they take minimum space in pipe lines.

For durable, tight seating—yet easy opening—seat rings and disc faces are brass. Crane 2-piece ball-type gland maintains uniform pressure on packing; prevents binding on stem; lengthens packing life. When specified, these valves can be fitted with gears, by-pass, and clean-outs; also can be motor or cylinder operated; non-rising stem, flanged or hub ends, up to 36-in.; O.S. & Y. type with flanged ends only up to 48-in. See your No. 49 Crane Catalog.

CRANE CO., 836 S. Michigan Ave., Chicago 5, Ill.
Branches and Wholesalers Serving All Industrial Areas

No. 793½, Outside Screw and Yoke. Working Pressures: 25 pounds steam or gas; up to 50 pounds cold water. Sizes: 10 to 48-inch.

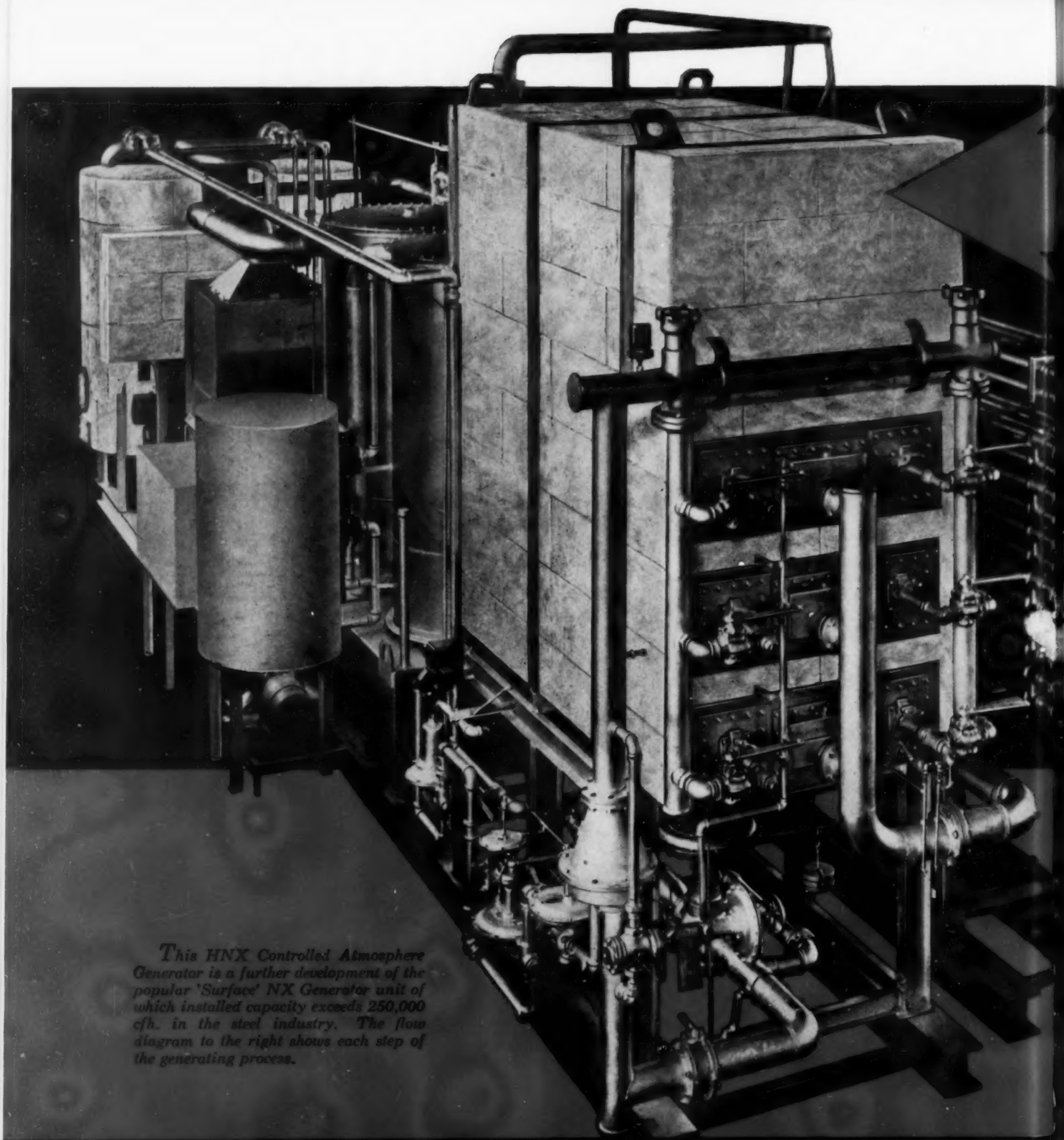
ONE ORDER TO CRANE COMPLETELY EQUIPS CIRCULATING, COOLING AND SERVICE WATER PIPING SYSTEMS



EVERYTHING FOR EVERY PIPING SYSTEM

CRANE

VALVES • FITTINGS • PIPE • PLUMBING AND HEATING



This HNX Controlled Atmosphere Generator is a further development of the popular 'Surface' NX Generator unit of which installed capacity exceeds 250,000 cfh. in the steel industry. The flow diagram to the right shows each step of the generating process.

SURFACE COMBUSTION CORPORATION • TOLEDO 1, OHIO

FOREIGN AFFILIATE COMPANIES

BRITISH FURNACES LIMITED—CHESTERFIELD
STEIN & ATKINSON, LTD.—LONDON

STEIN & ROUBAIX—PARIS, LIEGE AND GENOA
WILL L. SMITH, S.A.—BUENOS AIRES

One-Way Fired Soaking Pits

Billet Reheating Furnaces

Slab Heating Furnaces

Continuous Type, Controlled Atmosphere Strip Annealing and Normalizing Furnaces

Controlled Atmosphere Annealing Covers for Wire and Rod

Controlled Atmosphere Annealing Covers for Coil and Sheets

Continuous Furnaces for Heat Treatment of Steel Plate

Controlled Atmosphere Furnaces for Carbon Correction in High Alloy Rod and Bar Stock

Continuous Type Bright Annealing and Normalizing Furnaces

Prepared Gas Atmosphere Generating Equipment

Pit Type Convection Furnaces for Rod Annealing

Stress Relief Furnaces

Wire Patenting Furnaces

'Surface' HNX

CONTROLLED ATMOSPHERE

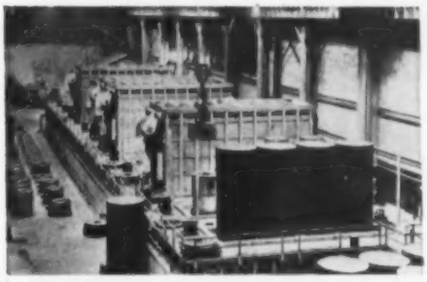
IMPROVES ANNEALING PRACTICE . . . PERMITS HIGHER STANDARD OF QUALITY IN STEEL MILL PRODUCTS

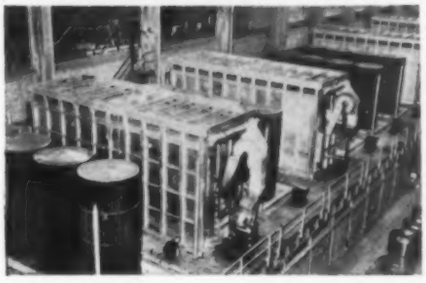
● HNX Controlled Atmosphere Gas is the newest modification of NX Gas and represents another step forward in research and development in controlled atmospheres for the processing of steel mill products. It is finding many applications where process requirements demand an inexpensive hydrogen-nitrogen protective atmosphere to assure top standards of quality.

Present applications of HNX Gas for the annealing of tin-plate stock have proved this atmosphere superior to others previously used, making possible a tin-plate stock of improved corrosion resistance. Eliminates "borders".

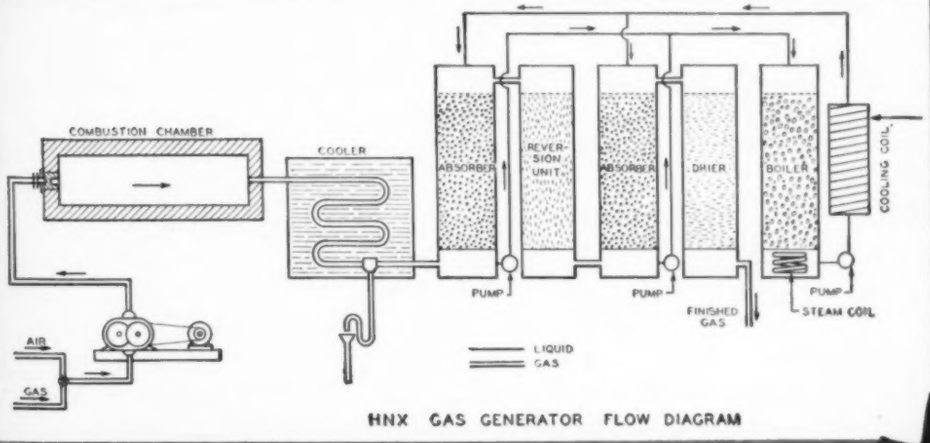
HNX Gas is not explosive and therefore serves as an excellent purge gas. At conventional mild steel annealing temperatures of 1150°F. to 1300°F. it provides complete surface protection for the steel when applied in the cover-type annealing furnace.

Invite a 'Surface' Engineer in for complete details.





Battery of 'Surface' lift-type annealing covers in a leading steel mill now using HNX gas for coil annealing.

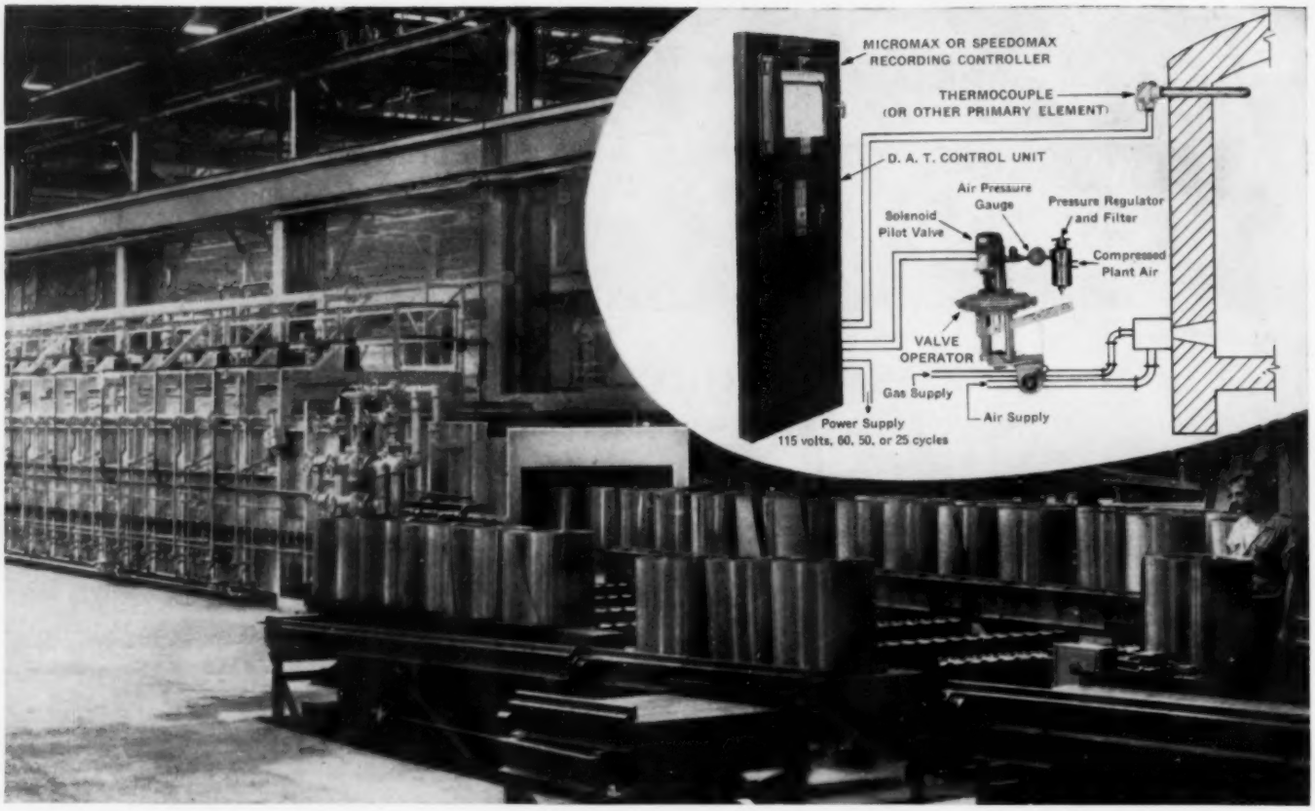


HNX GAS GENERATOR FLOW DIAGRAM

TYPICAL HNX GAS ANALYSIS

CO_2	Trace
CO	Trace
CH_4	Trace
H_2O	Dewpoint: (minus 40°F.)
H_2	3.0 to 10.0% (adjustable as required)
N_2	Remainder

'Surface' SERVES THE STEEL INDUSTRY



One of four 119-foot annealing furnaces built by Surface Combustion Co., and The Electric Furnace Co., for Scovill Manufacturing Company's new $10 million continuous strip mill. Crediting L&N D.A.T. pyrometric control on all these furnaces, Scovill says: "D.A.T. is taking a big part in helping us turn out the most uniform, high-quality brass we've ever made." Sheet is annealed in 2,000-lb coils; capacity is 32,500 lbs. per hour per furnace.

THIS "PACKAGE" OF CONTROL FITS ITSELF TO FURNACE NEEDS

And Only L&N Can Supply All Its Features!

SCOVILL'S latest success in controlling temperatures in brass strip-annealing furnaces is doubly interesting because it shows what can be done with other thousands of industrial furnaces. Small units may need only one instrument, instead of Scovill's five per furnace, but the principle's the same. Any furnace which can be controlled by turning fuel "on" at a predetermined low temperature, and turning it "off" at a predetermined high, will get its best possible regulation by D.A.T. Control.

D.A.T. excels for two reasons. First, it takes the "predetermined" out of the on-off action. Second, it adds full proportioning action. Instead of operating at predetermined temperatures, D.A.T. acts earlier or later, depending on change in heat demand. Only D.A.T. supplies all these features.

Increased production resulting from unusual uniformity is the great advantage of D.A.T. but other points are worth remembering: (1) Fuel can often be saved because less heat is lost up the stack. (2) Valve and burner sizes are not particularly critical. (3) D.A.T. can often modernize an old furnace, because it's so easy to install.

D.A.T. is just one of several L&N Controls. Call us for service or information in selecting equipment for any temperature-control problem. Address nearest office or 4942 Stenton Ave., Philadelphia 44, Pa.

TYPICAL RESULTS

D.A.T. exactly adapts its action to the upsets, load changes and lags of the furnace. This means it holds temperature in line for all normal changes in furnace charge, ambient temperature, temperature control point, etc.

D.A.T. offsets many inherent lags or delays in "sensing" temperature changes, such as that due to thermocouple protecting tubes.

D.A.T. operates equally well on furnaces of full-muffle, semi-muffle, open firing and conventional radiant-tube design.

MEASURING INSTRUMENTS · TELEMETERS · AUTOMATIC CONTROLS · HEAT-TREATING FURNACES

LEEDS & NORTHRUP CO.

Jrl. Ad. N-33A-626(6)

Alliance

FIRST IN SIZE
FIRST IN CRANE DESIGN

INDUSTRY WANTS SAFETY, YOU GET SAFETY WITH ALLIANCE CRANES

● Dependably safe! That's this 4-girder Alliance Ladle Crane. With a wide safety factor, it's engineered to operate 24 hours daily year after year with unbelievable minimum of maintenance. This powerful crane is equipped with an auxiliary trolley having a 60-ton and 20-ton hoist, safety rope reeving and synchronized worm drive, and a safety compartment containing a duplicate bridge master control. This lets the operator move the crane in safety in case hot metal is accidentally spilled. Another Alliance safety feature is the enclosed stairway leading from the cab to footwalk on the crane girder.

Known the world over, Alliance Cranes handle more hot metal than any other make. Alliance has constructed the largest cranes ever built considering height and capacity of lift.

Think now about giving your plant more lifting power by developing new cranes or reconverting old ones.

BIG CRANES

THE ALLIANCE MACHINE COMPANY

MAIN OFFICE
ALLIANCE, OHIO

PITTSBURGH OFFICE
1622 OLIVER BUILDING, PITTSBURGH, PA.

LADLE CRANES • GANTRY CRANES • FORGING MANIPULATORS • SOAKING PIT CRANES • STRIPPER CRANES • SLAB AND BILLET CHARGING MACHINES • OPEN HEARTH CHARGING MACHINES • SPECIAL MILL MACHINERY • STRUCTURAL FABRICATION

Specify N-B-M BRONZE CASTINGS

for higher steel mill production...lower costs!

Custom-engineered alloys — plus close foundry control — insures longer, more economical service

Longer life means less down-time . . . actual dollar-savings in the operating costs of your mill. You specify longer life when you specify N-B-M Bronze Castings . . . because of this important 3-Way Service offered by National Bearing Division:

Research . . . that in case after case has developed new alloys that roll up new tonnage records.

Engineering . . . that results in new and better designs to help solve old maintenance and production problems.

Facilities . . . for close foundry control that insures sound, dense castings—as-cast or machined to any degree of finish you desire.

From huge screw-down nuts to a complete line of Cored and Solid Bars for small bearings and bushings, put this 3-Way Service to work in your mill!

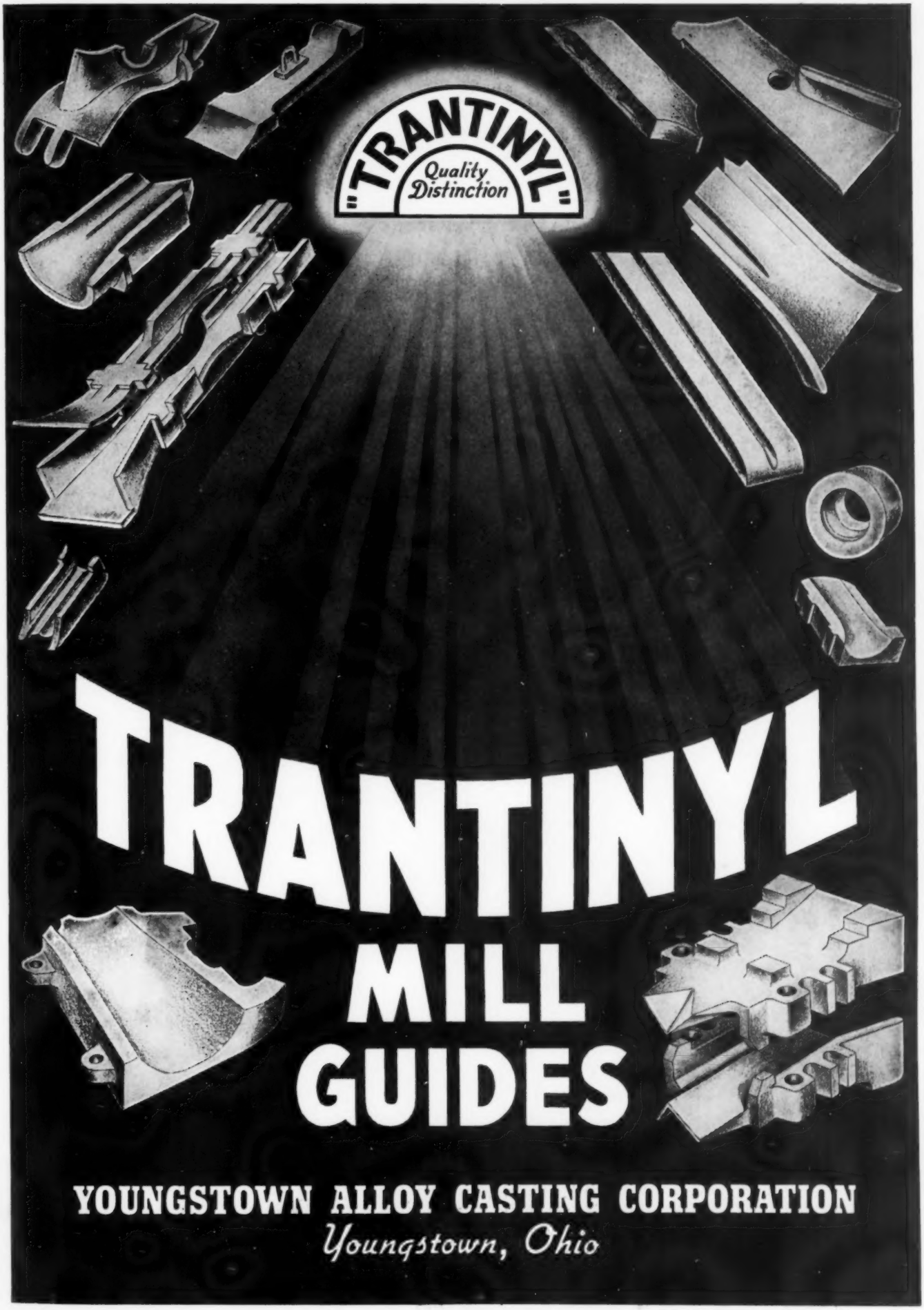
All types of Manganese, Aluminum, Nickel and High Tensile Bronze Alloys ...produced to your specifications or from our own service-proved formulas

AMERICAN Brake Shoe COMPANY

NATIONAL BEARING DIVISION

4936 Manchester Avenue • St. Louis 10, Mo.

PLANTS IN: ST LOUIS, MO • MEADVILLE, PA. • NILES, OHIO • PORTSMOUTH, VA. • ST. PAUL, MINN. • CHICAGO, ILL.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Quality Distinction
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GUIDES
YOUNGSTOWN ALLOY CASTING CORPORATION
Youngstown, Ohio

6 Reasons why Your Coke

Koppers-Becker Low-Differential Coke Ovens with Waste-Gas Recirculation are the most advanced ovens available and they have these advantages:

1. They make the best possible grades of domestic and metallurgical coke from suitable coals under widely-varying conditions with the least underfiring requirements, and the highest yields of byproducts.

2. They can be built (without interference with the uniformity of heating) in oven capacities up to 20 net tons of coal per oven charge, in small or large batteries, to suit local conditions.

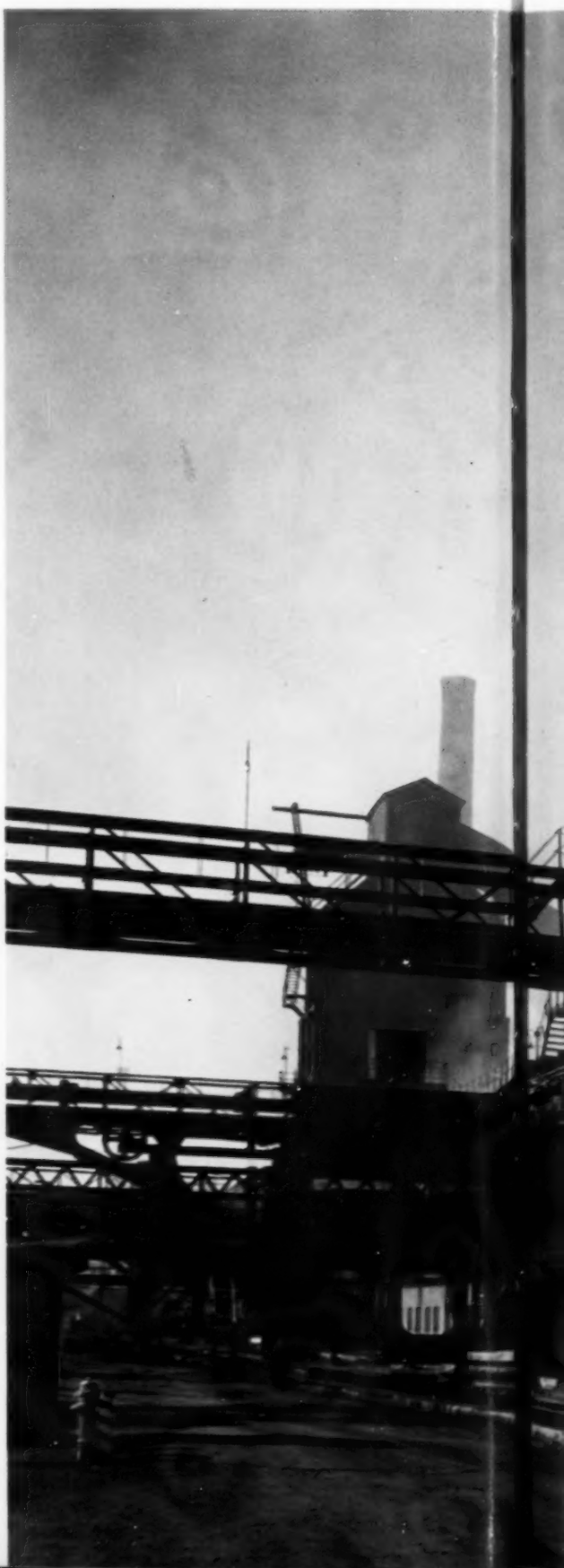
3. They can be underfired efficiently with coke-oven gas, natural gas, blue gas, carburetted water gas, propane, butane, high-B.t.u. refinery gas, producer gas or blast-furnace gas, producing uniformly heated coke over a wide range of coking times.

4. They are built of the best materials available and of sturdiest design; are free from complications; are simple to control, and accessible throughout, insuring low maintenance cost and long life.

5. They can be operated at high speed with greater safety and at lower flue-temperatures because of the action of the waste-gas recirculation system.

6. By means of a separate and efficient blast-furnace-gas-enriching system, they can be operated to produce as much coke when underfired with low-B.t.u. blast-furnace gas as when underfired with coke-oven gas with the least requirement of high-B.t.u. coke-oven gas for enriching.

Koppers engineers will be glad to work with you on your plans for coke oven plants, light oil plants, by-product plants, gas-purification systems, gas producers, precipitators and any other equipment or apparatus connected with coal carbonization.



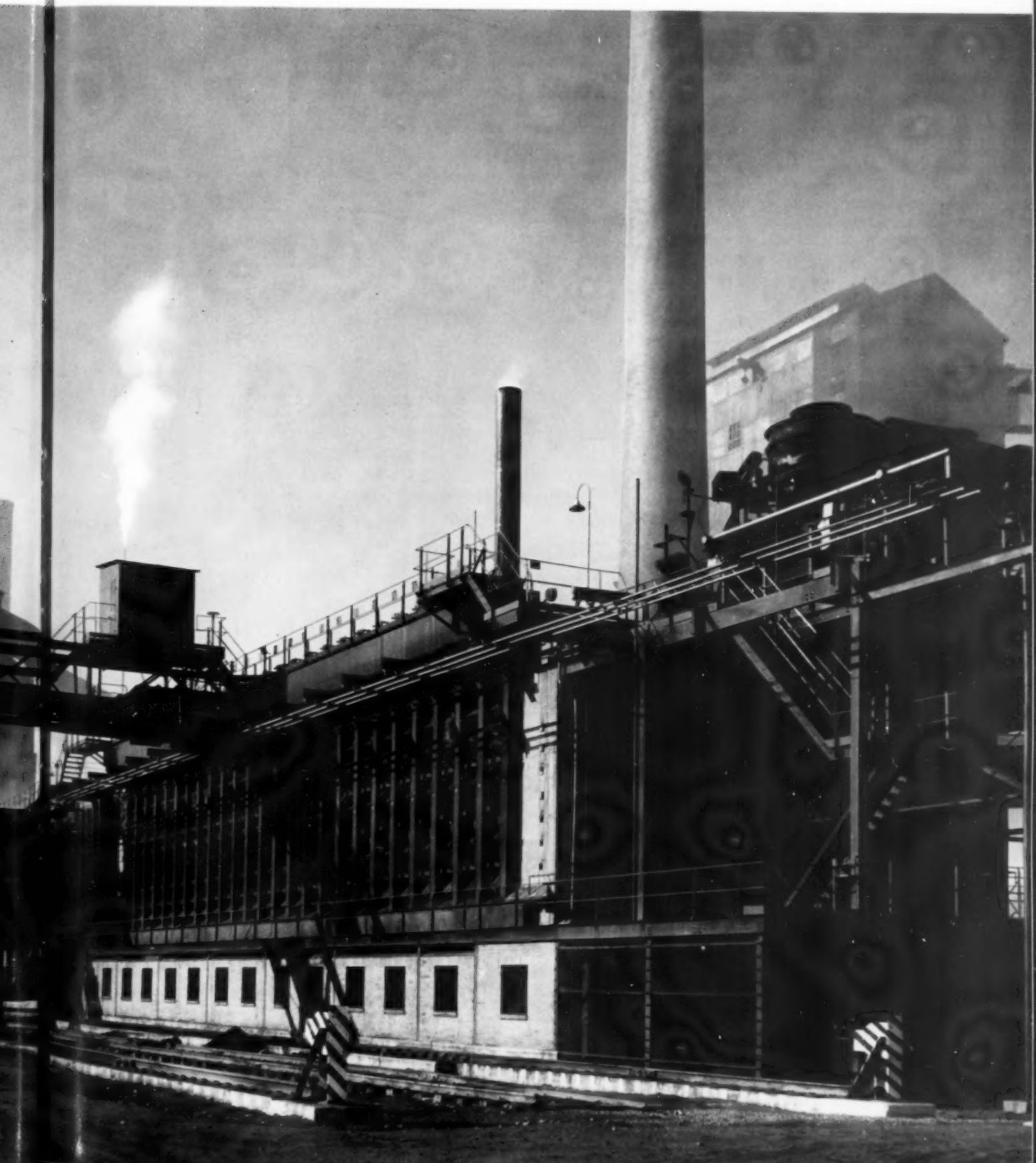
KOPPERS COMPANY, INC.

ENGINEERING AND CONSTRUCTION DIVISION

Pittsburgh 19, Pa.

KOPPERS

Oven Plant should be built by Koppers



PARALLOY

REGISTERED TRADE MARK

A name of Quality in

- PINCH ROLLS
- COILER ROLLS
- TENSION ROLLS
- STEEL MILL ROLLS

NO SCRATCHING OR GALLING

500-600-BRINNEL

MORE TONS PER PASS

OTHER PRODUCTS

HYDRAULIC SLAB AND BILLET PILERS
STRIP AND SHEET OILING EQUIPMENT
SHEET SCRUBBER AND CLEANING LINES
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HOT BEDS—COOLING BEDS—TRANSFERS
BILLET EJECTORS—PINCH ROLL STANDS
SLITTERS—SPECIAL SHEARS AND GAUGES
TILTING TABLES—TRAVELING AND LIFTING TABLES
CONTINUOUS PICKLING LINES—ROLLER LEVELLERS
FURNACE CHARGING EQUIPMENT—FURNACE PUSHERS
STRIP STEEL COILERS AND REELS—SCRAP BALLERS
RAILROAD SPIKE FORMING MACHINES— ROLL LATHES
SHEET GALVANIZING LINES—WIRE PATENTING FRAMES
STRETCHER LEVELLERS—ANGLE AND SHAPE STRAIGHTENERS
ROLLING MILL TABLES—GEAR AND INDIVIDUAL MOTOR TYPES
MACHINERY BUILT TO CUSTOMER'S DESIGN AND DETAIL DRAWINGS

DUCTILE CASTINGS 80000 PSI

The Youngstown Foundry & Machine Co.

Youngstown, Ohio

OVER SIXTY YEARS OF SERVICE TO THE STEEL INDUSTRY

STOP RUST!

YOU can STOP RUST . . . PREVENT RUST...on *any* rustable metal surface with RUST-OLEUM. Every day, rust eats away on your metal tanks, buildings, fences, stairs...everything metal inside and outside your plant. Yet, rust *can* be stopped and protection given economically with RUST-OLEUM.

For more than a quarter of a century RUST-OLEUM has been *proved* under severe conditions of weather, fumes, salt air, salt spray, and other rust producing conditions. Railroads, shipyards, builders, refiners...nationally known users* in almost every field of industry...have found RUST-OLEUM the economical way to stop rust and prevent further rust. Architects, builders, engineers, maintenance men now specify RUST-OLEUM for primer, "shop coat", and finish coats.

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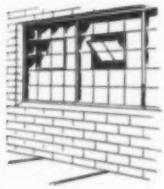
Be sure you get *only* genuine RUST-OLEUM for positive protection against rust! Specify RUST-OLEUM to your contractor or architect on any new construction, remodeling or maintenance work.

RUST-OLEUM is stocked and sold by leading industrial distributors in all principal cities of the United States and Canada. See Sweets for complete catalog and nearest source of supply, or write us direct for complete information. **Names on request*

RUST-OLEUM CORPORATION

2444 OAKTON STREET EVANSTON, ILLINOIS



"Job-Engineered" means tailored to your crane needs

When you buy a crane, you want dependable service for many years to come. Your P&H "Job Engineered" crane will be built to meet your requirements to insure dependability . . . ample reserve capacity . . . adequate service factor . . . maximum safety. All P&H electrical equipment is designed and built by P&H for crane service — not adapted for it.

"Job Engineered" is an Added Value which comes with P&H's 65-year experience in crane-building — to serve your needs *exactly*.

And here's a fact worth remembering: P&H Cranes are sold and serviced by factory-trained men — not agents.

P&H Magnetorque* is the greatest advancement in AC crane control in the past 40 years. Ask about it.

*T. M. of Harnischfeger Corporation for electro-magnetic type brake.

EXCAVATORS • OVERHEAD CRANES • HOISTS • ARC WELDERS AND ELECTRODES • SOIL STABILIZERS • CRAWLER AND TRUCK CRANES • DIESEL ENGINES • CANE LOADERS PRE-ASSEMBLED HOMES

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4455 West National Avenue
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HARNISCHFEGER CORPORATION

P&H

Write for your copy of Bulletin C-39 describing P&H Magnetorque control.

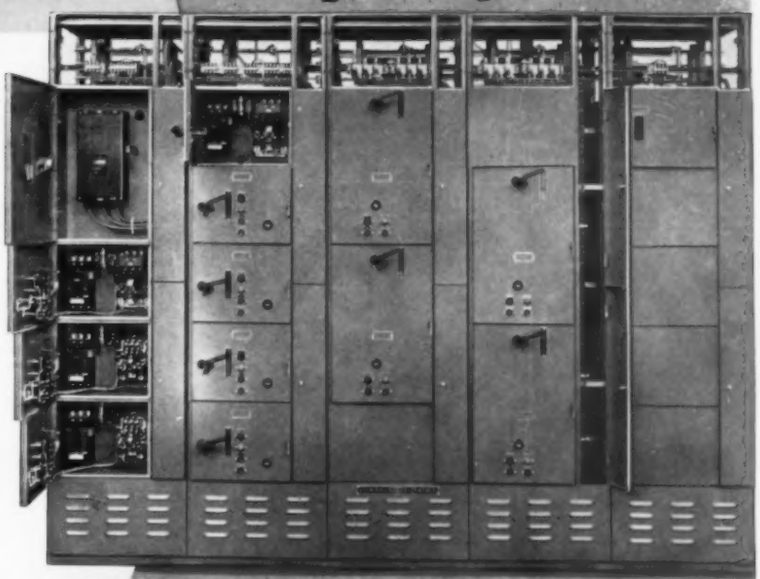
OVER 17,000 P&H CRANES SERVE AMERICAN INDUSTRY . . . FAR MORE THAN ANY OTHER

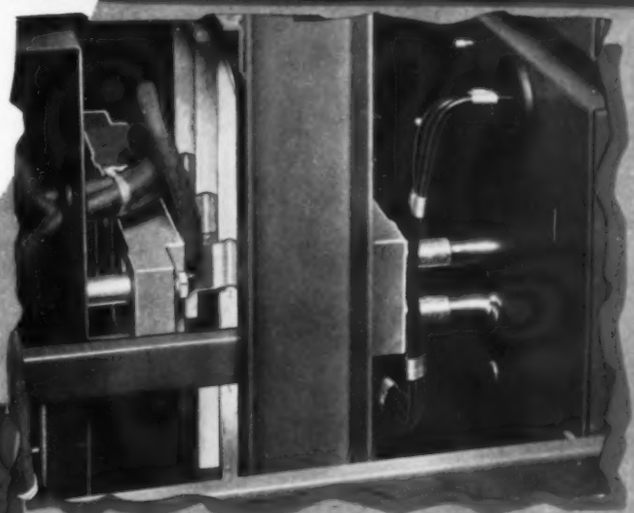
CLARK *can cut your A. C. Control space requirements by 50%!*

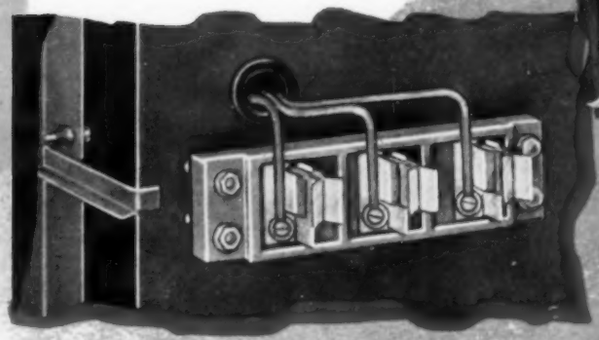
The Clark Bulletin 6200 BACK-TO-BACK type CONTROL CENTERS accommodate *double the number* of compartments in exactly the same space as occupied in the front-line type. Thus space requirements are cut 50%.

Both types are 90 inches high, 24 inches wide, 20 inches deep and have 6-inch vertical wiring troughs with separate front-opening doors.

Both types have plug-in type motor starter compartments, with or without auxiliary equipment, and both have segregated ventilated spaces for feeder bus, and terminals for motor and control leads.







Top illustration shows a typical CLARK CONTROL CENTER with various sizes of compartments.

Middle illustration shows a close-up of the BACK-TO-BACK construction.

Bottom illustration shows a close-up view of VISE-GRIP PLUG-IN clips.

CLARK CONTROL CENTERS accommodate any number of desired combinations of A. C. motor starters through NEMA Size 5, and auxiliary equipment.

For neat, compact, orderly space-saving housing of A. C. motor control equipment: CLARK CONTROL CENTERS.

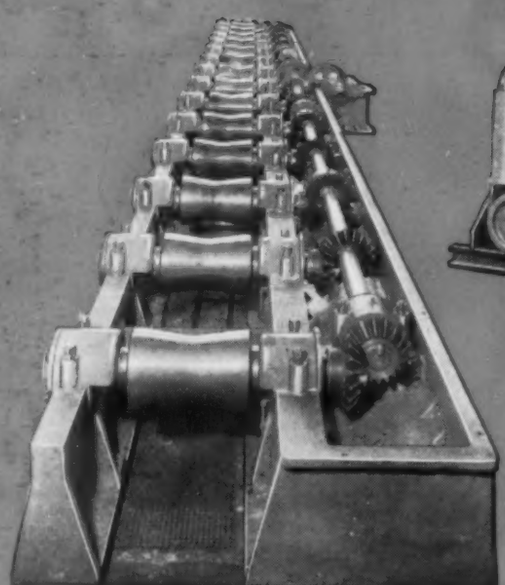
THE CLARK CONTROLLER CO.

ENGINEERED ELECTRICAL CONTROL • 1146 EAST 152ND STREET, CLEVELAND 10, OHIO

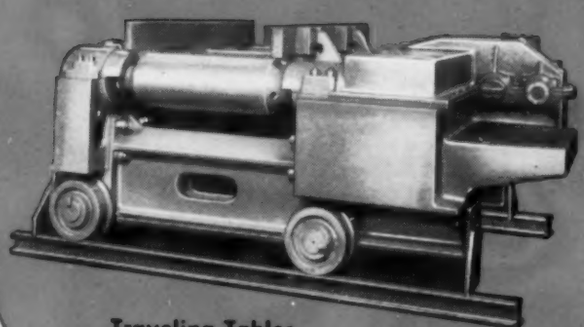
Continental

MILL TABLES

for every purpose, for all mills



Tube Mill Tables



Traveling Tables

Merchant Mill Tables

PRODUCERS OF: Complete Rolling Mill Installations including:

Blooming Mills
Structural Mills
Bar Mills
Billet Mills
Merchant Mills

Plate Mills
Slabbing Mills
Universal Mills
Hot Strip Mills
Cold Strip Mills

Non-Ferrous Mills
Roll Lathes
Ingot Mold Cars
Charging Box Cars
De-Pilers

Tables
Transfers
Shears and other auxiliary steel plant equipment

IRON, ALLOY IRON and STEEL ROLLS for ferrous and non-ferrous rolling mills; pulp and paper industry; textile industry; and milling, cereal and vegetable oil industries.

CARBON and ALLOY STEEL CASTINGS from 20 to 250,000 pounds. Complete heat treating and machining facilities.

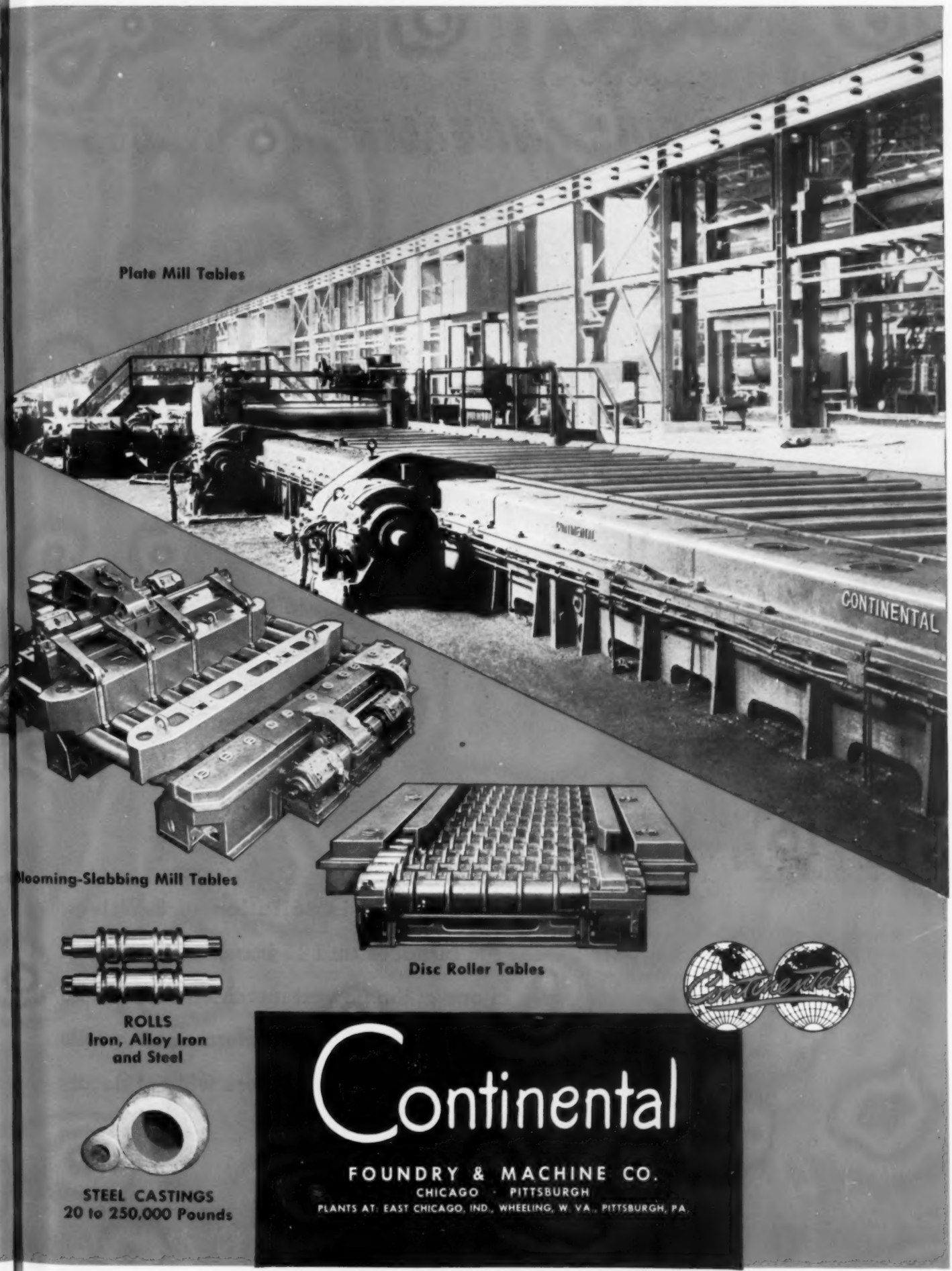
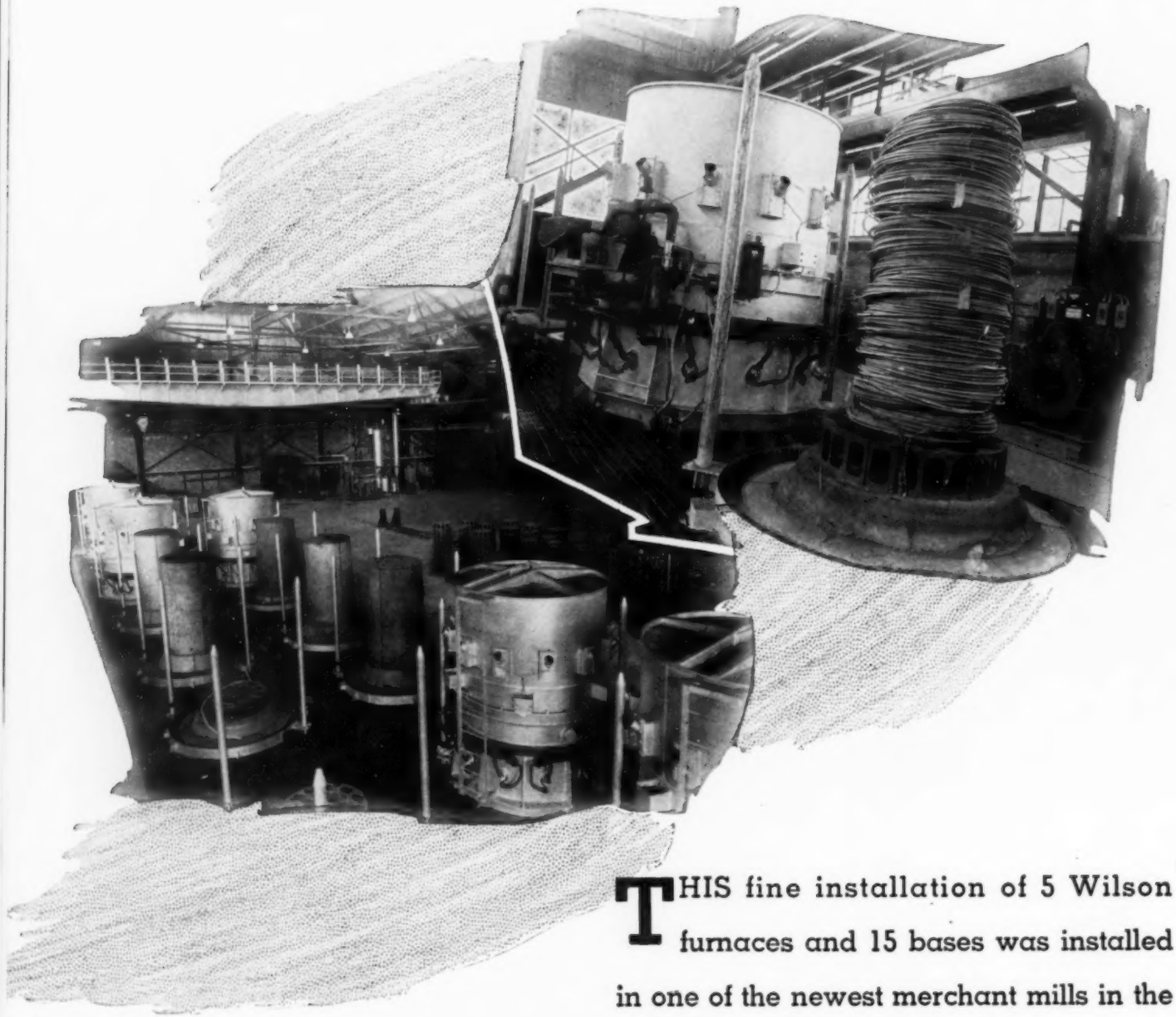


Plate Mill Tables
CONTINENTAL
Blooming-Slabbing Mill Tables
Disc Roller Tables
ROLLS
Iron, Alloy Iron
and Steel
STEEL CASTINGS
20 to 250,000 Pounds
Continental
FOUNDRY & MACHINE CO.
CHICAGO · PITTSBURGH
PLANTS AT: EAST CHICAGO, IND., WHEELING, W. VA., PITTSBURGH, PA.

WILSON

MERCHANT COIL ANNEALING FURNACES



THIS fine installation of 5 Wilson furnaces and 15 bases was installed in one of the newest merchant mills in the steel industry to anneal merchant bar coils in a controlled atmosphere without decarburization.

Lee Wilson

ENGINEERING *Co., Inc.*

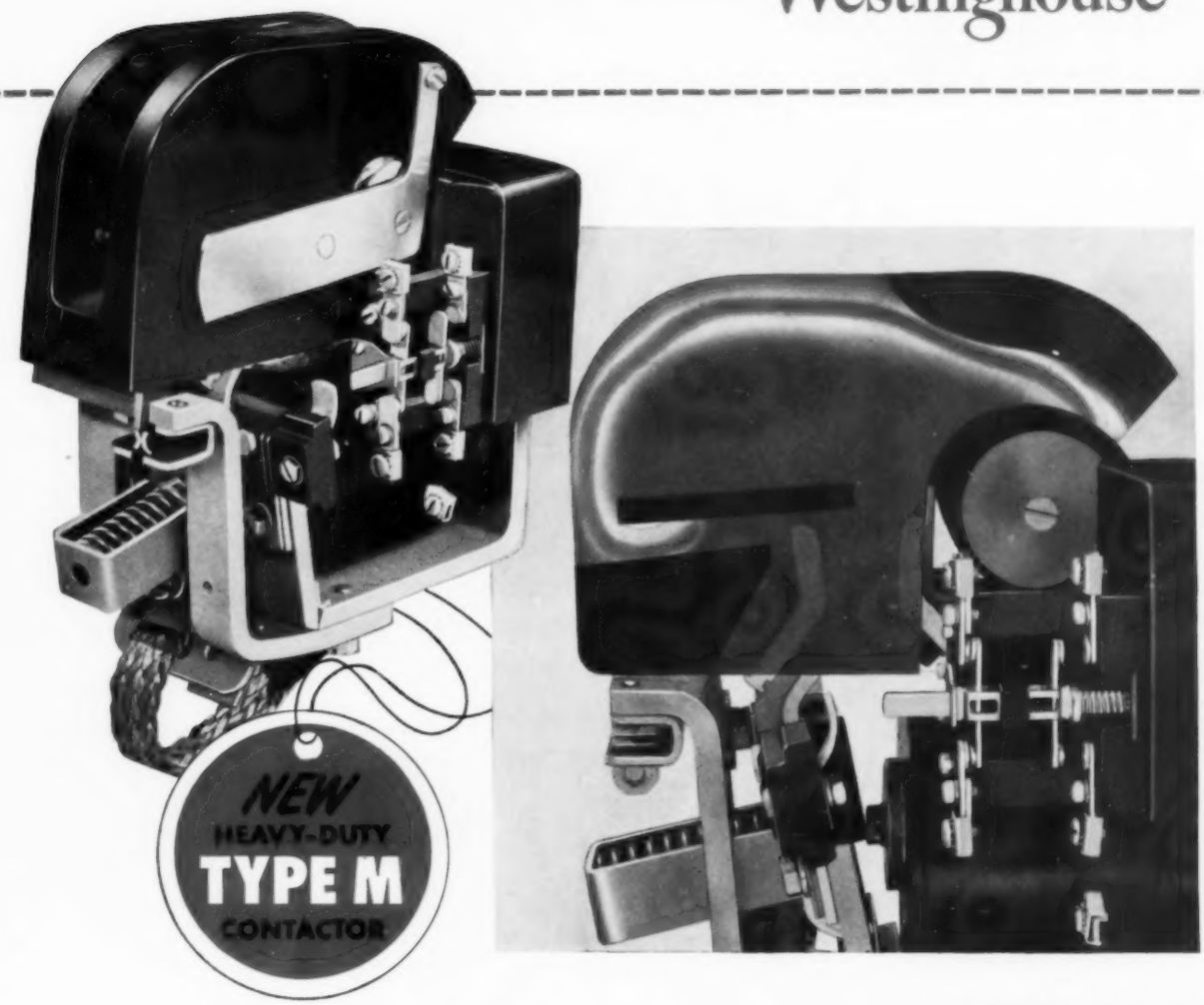
20005 WEST LAKE ROAD • CLEVELAND, OHIO

Telephone ACademy 1-4670

INDUSTRIAL FURNACES ★ RADIANT TUBE HEATING ★ HEAT TREATING PROCESSES

YOU CAN BE **SURE**.. IF IT'S

Westinghouse



HOT ARCS STOPPED *COLD!*

When a d-c contactor opens under load, hot arcs leap between opening contacts. Burning with terrific heat, arcs bead and pit contact area—unless they are controlled and extinguished *quick*.

Arcs don't have a chance in the Westinghouse D-C Type M Contactor. In half a wink—less time than it takes contacts to open fully—the exclusive double-pocket, "Qwik-Quench" arc box with special side-plate design increases blowout flux density across the contacts . . . speeds the arc to the arc horns . . . and extinguishes it. Action is *fast*.

Result? Contacts stay clean . . . need less service . . . last longer . . . stand up to millions of make-breaks under heavy loads. Arc boxes last longer.

Fast arc quenching is but one feature of new Type M Contactor. Ask your Westinghouse representative to tell you about the unit construction . . . the self-cleaning knife-edge bearing . . . the unit-mounted interlocks, and other exclusive Type M features.

Call him today for a copy of B-5261 and the complete Type M story. Or write Westinghouse Electric Corporation, P. O. Box 868, Pittsburgh 30, Penna.

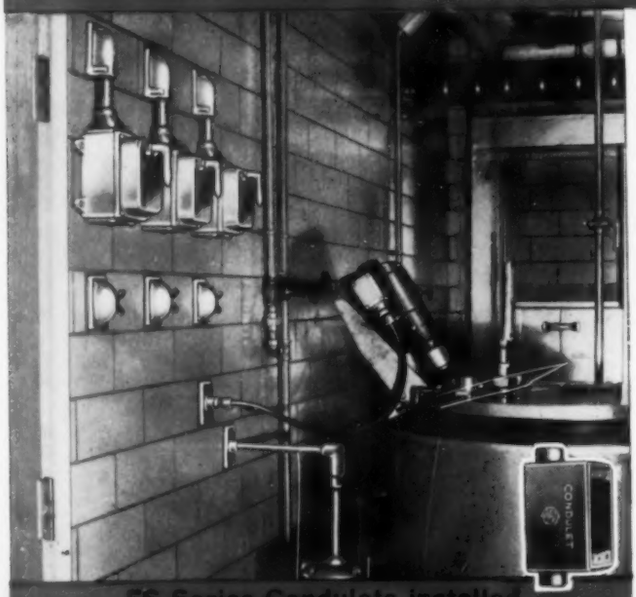
J-27001

Westinghouse

STEEL MILL

MOTORS AND CONTROLS

the CONDULET* and rigid conduit method gives you maximum

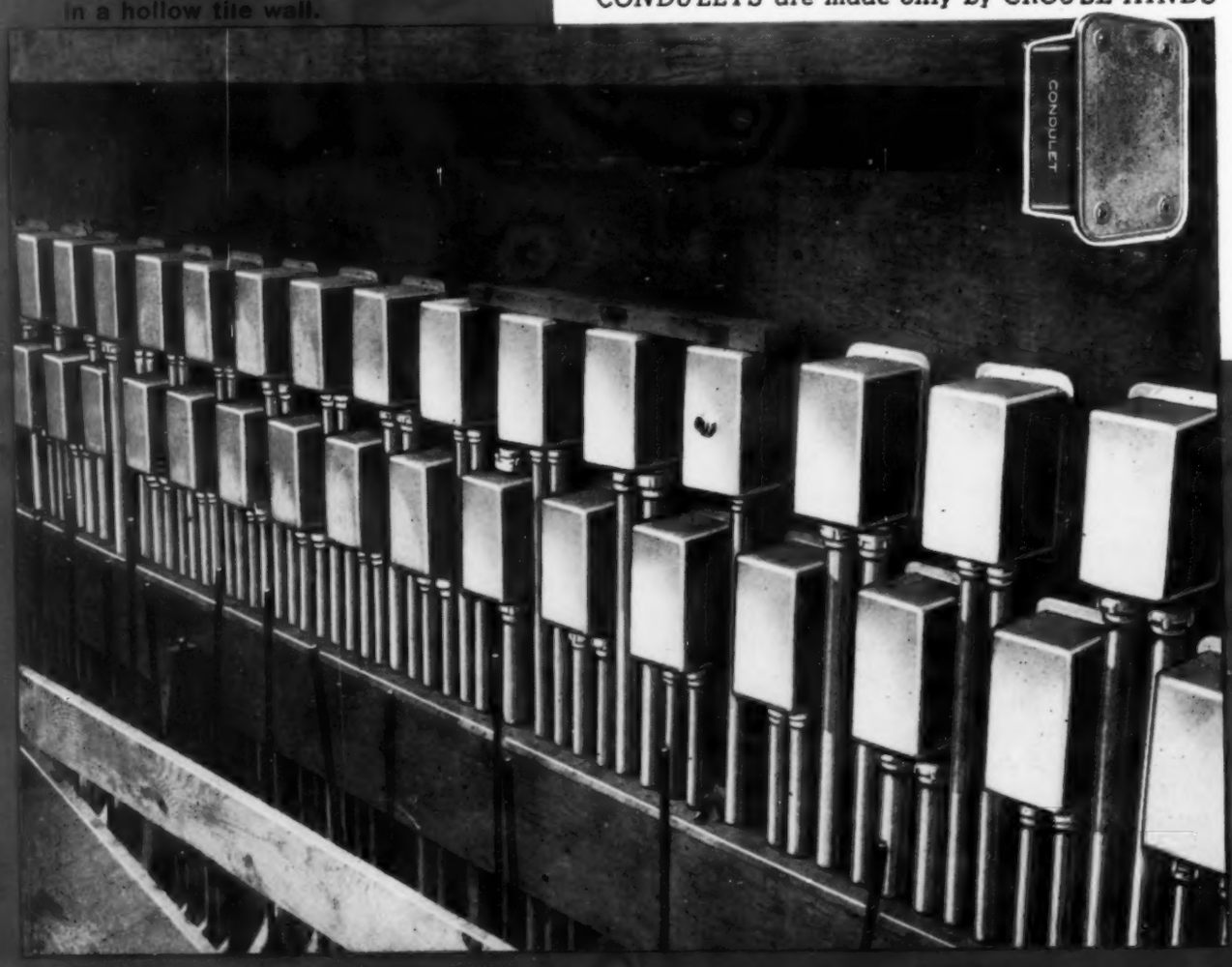


FS Series Condulets installed in a hollow tile wall.

PROTECTION and SAFETY in concealed work

When you plan a job of concealed electrical wiring, every factor that has a bearing on the kind of service it will give throughout the life of the installation should be carefully considered.

***CONDULETS are made only by CROUSE-HINDS*



Type AEQ Condulets, with brazed hubs, placed in position on concrete forms.

For MODERN WIRING . . . the CONDULET and conduit method gives you definite advantages

1 **ECONOMY** . . . Add up the material and the installation costs and you will find that Condulets and rigid conduit compare favorably with other wiring methods. Then consider the other advantages and you will find that Condulet and rigid conduit is the really economical method that pays extra dividends over the years.

2 **GROUND CONTINUITY** is of vital importance in concealed work because any joint that isn't tight in the beginning makes a high resistance point and after the concrete has been poured there is never any way to locate and correct the faulty condition. CONDULETS, with their taper threaded hubs, and rigid conduit with its tapered threads make a secure joint that provides a reliable and permanent low resistance path to ground. This SAFETY feature affords maximum PROTECTION against personal injury and fire.

3 **CORROSION RESISTING** . . . Cast Feraloy Condulets offer the best PROTECTION wherever moisture, dust, or corrosive atmospheres are present. This quality is very important in concealed work because corrosive tendencies are greatest where there is a change of medium, as at the point between the floor or wall and the air.

4 **FLEXIBILITY** . . . In concealed work Condulets with blank covers can be placed at strategic locations to provide future outlets to meet changing conditions.

5 **SECURE ATTACHMENT OF DEVICES** . . . The mounting holes in CONDULETS are drilled and tapped in the cast metal body — no weak mounting ears to twist off. All devices are FIRMLY attached.

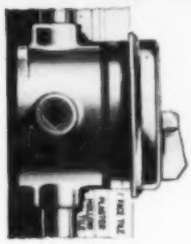
6 **QUALITY** . . . For more than forty-five years CONDULETS, made only by CROUSE-HINDS, have been the standard of quality, built from the finest materials, with painstaking care, by skilled craftsmen.

7 **VARIETY** . . . There are thousands of types and sizes of CONDULETS, plugs and receptacles, and lighting fixtures including a complete explosion-proof and dust-tight line for use in hazardous locations.

On your next job of concealed work, plan to get all of the benefits of sturdy Cast Feraloy CONDULETS and rigid conduit. Send for additional information on modern CONDULET installation.

CROUSE-HINDS COMPANY
Syracuse 1, N. Y.

Offices: Birmingham — Boston — Buffalo — Chicago — Cincinnati — Cleveland — Dallas Denver — Detroit — Houston — Indianapolis — Kansas City — Los Angeles — Milwaukee Minneapolis — New York — Philadelphia — Pittsburgh — Portland, Ore. — Salt Lake City San Francisco — Seattle — St. Louis — Washington. *Resident Representatives:* Albany Atlanta — Baltimore — Charlotte — New Orleans — Richmond, Va.
CROUSE-HINDS COMPANY OF CANADA, LTD., TORONTO, ONT.



Type EHS Explosion-Proof Switch Condulet in a hollow tile wall

GUA Series Explosion-Proof Condulets with lugs for nailing to concrete forms.

Type AD Watertight Condulets for flush mounting in floors or walls.

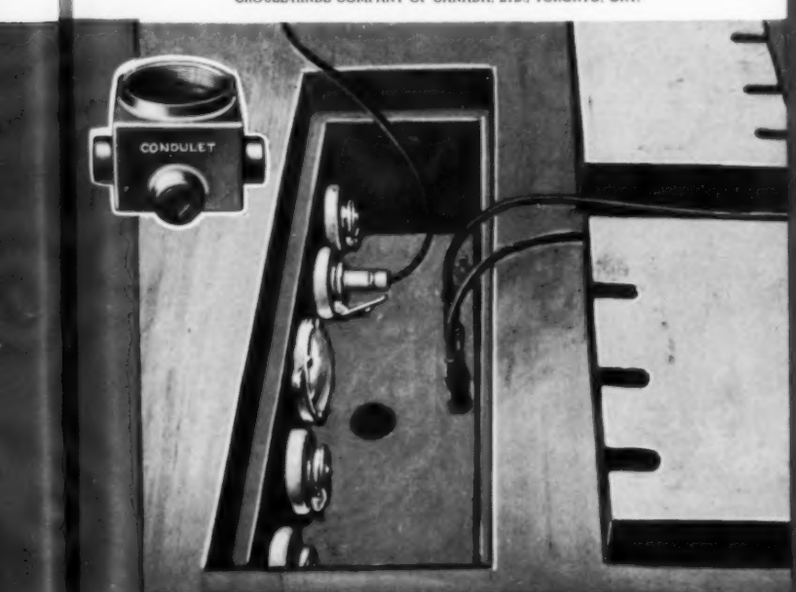
Type FJC Condulets for floor outlets. Covers can be drilled and tapped.

GRF Series Condulets with slotted nailing lugs.

SK Series Condulets with nailing lugs. For walls, floors or sidewalks. Have flush cover screws.

Type SKC Condulet and Type EY Large Radius "Y" installed in concrete.

A Nationwide Distribution Through Electrical Wholesalers



Explosion-Proof Type GUB Junction Condulet and Type CPS Arktite Plug Receptacle Condulets in a concrete pit

Type LT Large Radius Tees in position for pouring a concrete floor.

Type AEQ Arktite Plug Receptacle Condulets in a concrete pit

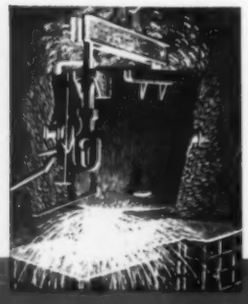
UNION ARMOR STEEL CASTINGS...

are more economical for important equipment like this!

If you are one of those mill maintenance men on the lookout for production economies consider this: Universal type Couplings and Spindles cast from our special high-strength alloy steels actually *cost less . . . last longer . . . are easier to machine. Fewer spares needed.* To prove these claims, "Union" Sales Engineers have documented performance data and prices they would like to compare with your own figures. An interview at your convenience involves no obligation whatever. Write us today.

"UNION" makes better: **CHARGING BOXES • PEELS • INGOT SLAG & POT CARS • CHARGING BOX CARS • UNIVERSAL COUPLINGS AND SPINDLES GEARS AND PINIONS • ALLOY TONGS • SPECIAL ALLOY CASTINGS**

CASTINGS CAN BE FURNISHED ROUGH OR MACHINED



UNION STEEL CASTINGS

DIVISION OF BLAW-KNOX COMPANY . . . PITTSBURGH 22, PA.

Crops *and* Shorts

REPORTS from iron and steel producers to Commerce Secretary Sawyer show actual commitments for expansion as follows: Last half of 1950, 2,469,000 tons of ingots and 128,000 tons of iron; in 1951, 3,972,000 tons of ingots and 1,084,000 tons of iron; and in 1952, 2,959,000 tons of ingots and 545,000 tons of iron. These additions will give annual capacities of 109,963,000 net tons of ingots and 73,378,000 tons of iron by the end of 1952.

▲

WHEN we read some statistical surveys we are reminded of the story about the student who found that the families of Princeton graduates averaged 1.8 children, while the families of Smith graduates averaged 1.4 children, and who then concluded that men have more children than women.

▲

THE White House has said that it firmly believes that price controls and rationing are not necessary if production is expanded sufficiently to give enough appliances, etc. And of course the steel industry is a principal target in the push for faster expansion. This expression of faith in the law of supply and demand seems strangely at odds with the same administration's policy of support for farm prices to keep them artificially high.

As we've said before, what's sauce for one goose isn't sauce for a lot of geese.

▲

A SIMILAR gem of inconsistency is the report of the Senate Agricultural Committee which asks for an investigation of the sales and storage practices of the National Federation of Coffee Growers, of Colombia, South America. This organization is a government-supported co-operative that makes loans to coffee growers, and stores coffee taken in under these loans. It is believed this results in raising the price of coffee.

In the United States, the Commodity Credit Corporation, a government agency, does exactly the same thing on potatoes, butter, eggs, wheat, corn, cotton, peanuts, etc., and operated last year with a net loss of $249,000,000.

▲

WHEN you find the months speeding by faster and faster, you're either getting old or you're buying on the installment plan.

▲

SPEAKING before the annual meeting of the Philadelphia chapter of the National Association of Purchasing Agents, B. F. Fairless, president of United States Steel Corp., said: "After hearing from Washington officials, occasional customers, assorted labor leaders and a couple of stockholders, I have to come to the conclusion that the only way a corporation executive can get a kindly word from anybody these days is to accept a speaking engagement at a dinner where the toastmaster is a friend of his."

▲

IT'S all a matter of degree. If you owe $50, you're just a poor credit risk. If you owe $50,000, you're a business man. If you owe $50,000,000, you're a tycoon. If you owe $50,000,000,000, you're the government.

▲

SHIPMENTS of steel products for the first seven months of 1950 were the highest ever made in the similar period of any year — 40,232,505 net tons. The total payroll for the iron and steel industry in the first seven months of 1950 was over $1,324,000,000, likewise the highest ever reached in a similar period.

▲

WE thoroughly agree with Dr. George W. Crane in his statement: "There is no future in any job. The future lies in the man holding the job." But various individuals who interview young men for jobs in industry say that many applicants seem more interested in pension plans than they are in the job itself. With this kind of thinking, can there be a future?

▲

IT may never land on the hit parade but an original song presented at the Old Timers dinner in Cleveland by its author, Jim Addleman, goes in part:

There are engineers and engineers
of many, many kinds.
There are engineers and engineers
From many, many climes.
But of any kind that comes to mind
There's one who has no peer.
He's the sound and steady, always ready —
Steel Mill Engineer.
He will build it up or tear it down
Or move it where it ain't.
He will calculate or operate
From layout to the paint.
And as you all know, where e'er you go
You'll never, never hear
Anything but praise for all his ways, the —
Steel Mill Engineer.
He has bragged and told he won't grow old.
He says he'll never die.
So he strips the coal in the strip mines,
Enjoys life on the sly.
Oh, he's not the wreck you might expect,
His age is just veneer.
Though he may be old, his heart's not cold. He's a
—Steel Mill Engineer.

▲

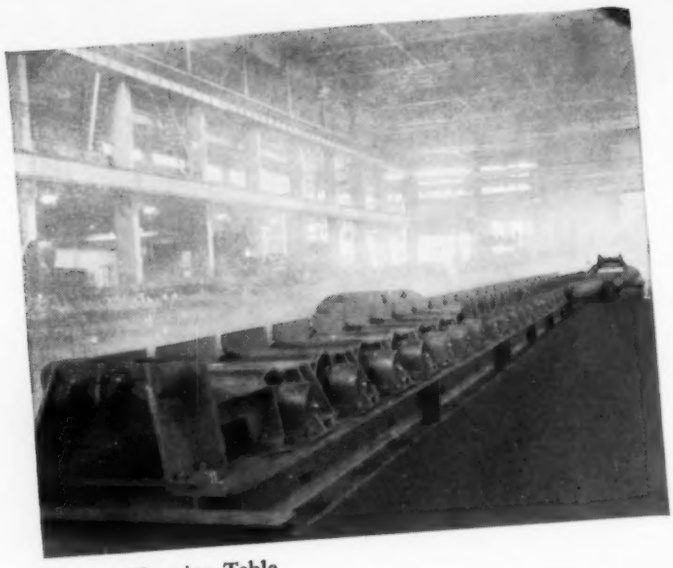
THE sad thing about the national debt is that future generations are not here now to see the magnificent things we are doing with their money.

▲

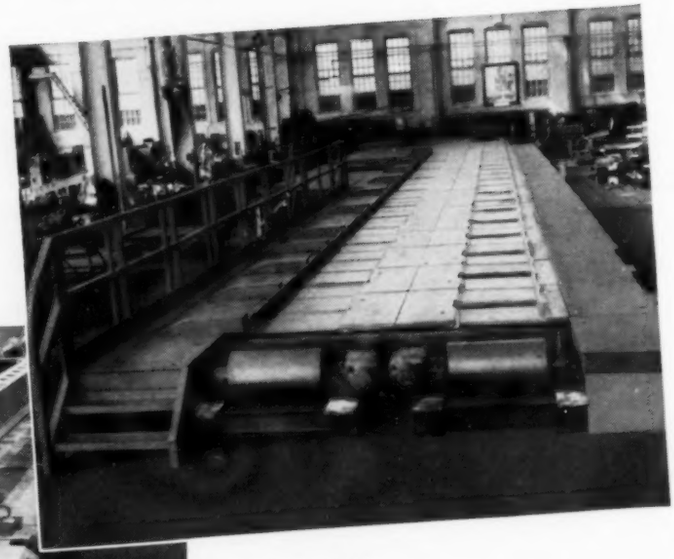
I'm all for higher taxes,
I think they would be fine,
Provided that they start in
The bracket over mine.

Birdsboro Engineering

at home and in the field is responsible for the *design, construction* and *installation* of rugged, dependable steel mill machinery which is helping industry of the world produce durable goods faster — and more economically.



Furnace Charging Table



14" Mill Table

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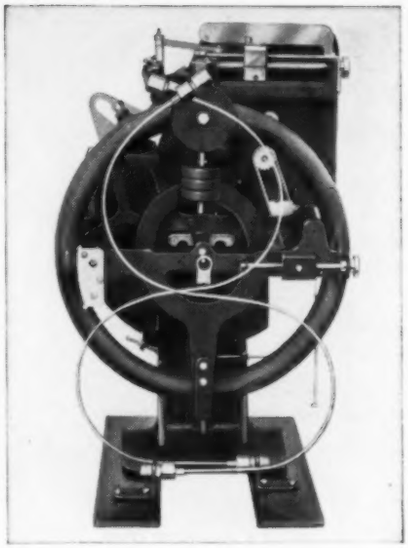

Rear View of Hagan Ring Balance Meter with single high-differential ring. Integrator is at upper right.

Same orifice . . .
same meter body . . .
full scale differential
continuously adjustable from
20 to 140 inches

with HAGAN

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Hagan Dual Meter with two low differential rings. Integrator can be provided for each ring if desired.

Dual Meter case occupies same panel space, and is only 5 inches deeper than single-ring case.

The Hagan Ring Balance Flow Meter is not a "fixed-head" meter but can be adjusted to accommodate a change of as much as 7 to 1 in maximum head—with full scale chart reading.

This is accomplished by a spring resistance system which is adjusted by a simple range screw. Especially at low flows, this system gives high accuracy in the conversion of differential head to pen movement.

Other models of this meter are available for heads of two inches or lower, and up to 420 inches — and each has this same easy adjustability.

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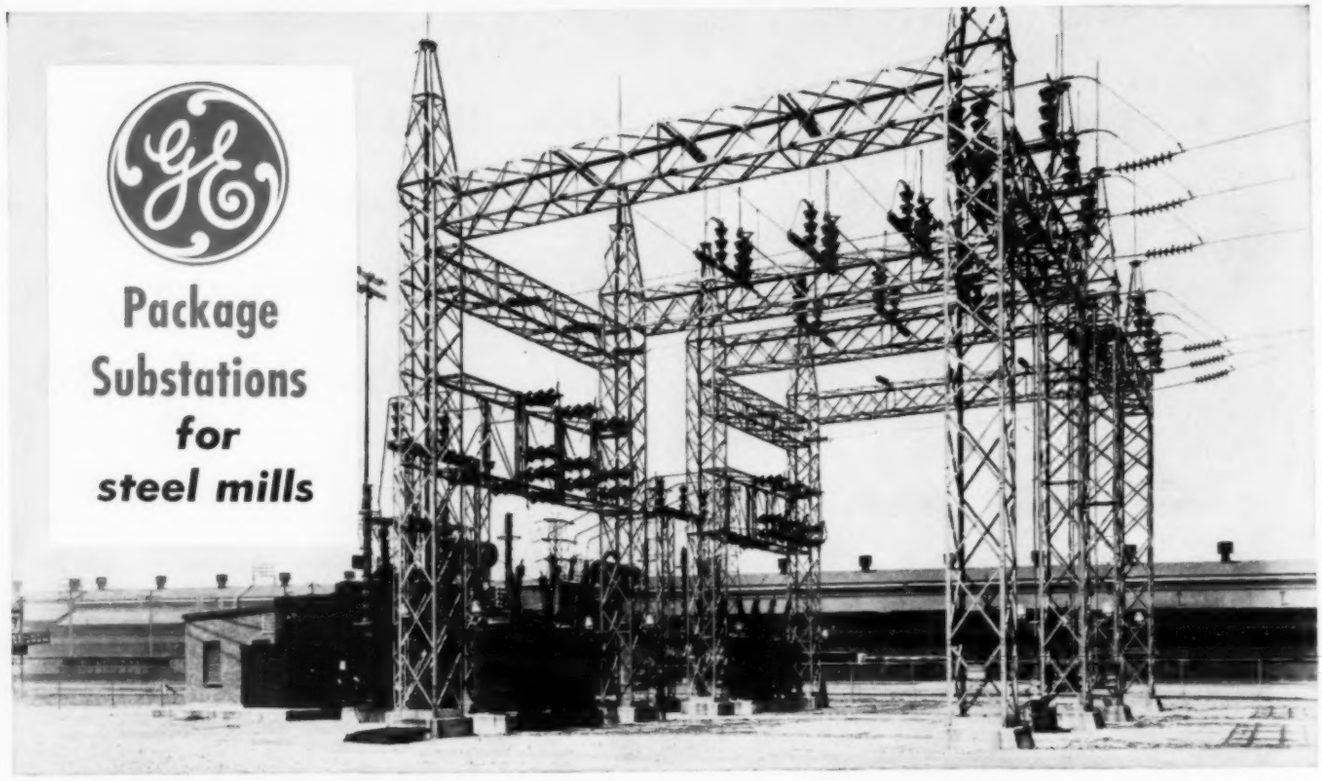

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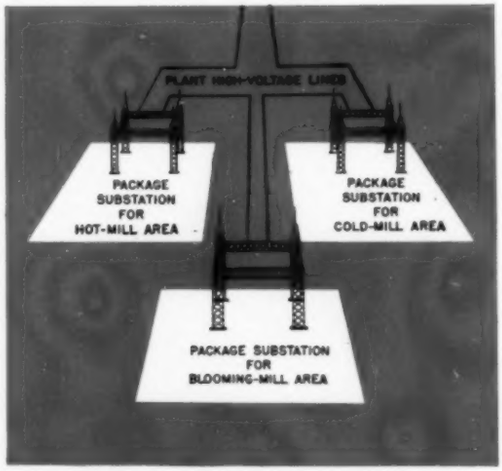
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Iron and Steel ENGINEER

OCTOBER, 1950 VOLUME XXVII NUMBER X

In This Issue

Technical Aspects of Northern and Southern Blast Furnace Practice — by C. G. Hogberg, Assistant to Chairman Blast Furnace Committee, United States Steel Corp. of Delaware, Pittsburgh, Pa..... 37

Properties of Available Blast Furnace Refractories — by M. A. Fay, Ceramic Engineer, General Refractories Co., Philadelphia, Pa..... 55

Developments in the Design of Coal and Ore Bridges — by B. A. Rose, Director of Engineering, Heyl & Patterson, Inc., Pittsburgh, Pa..... 60

Power Truck Transportation in Steel Plants — by Charles S. Schroeder, Director of Engineering, The Yale & Towne Manufacturing Co., Philadelphia, Pa..... 66

The Midland Works of Crucible Steel Co. of America — by T. J. Ess.....following page 68

Cold Rolling of Tinplate — by G. E. Stoltz and J. W. Brinks, Westinghouse Electric Corp., Pittsburgh, Pa..... 69

Current AISE District Section Meetings..... 89

An Improved D-C Crane Hoist Control — by S. Rifkin, Industrial Engineering Divisions, General Electric Co., Schenectady, N. Y..... 90

Stud Welding Speeds Steel Production — by Robert C. Singleton, Nelson Stud Welding Div., Morton Gregory Corp..... 100

Pictorial Roundup — AISE Convention and Iron and Steel Exposition..... 106

Date Line Diary..... 109

Industry News..... 119

Personnel News..... 135

Equipment News..... 151

Index to Advertisers..... 163

Published Monthly by
ASSOCIATION OF IRON AND STEEL ENGINEERS
1010 EMPIRE BUILDING
PITTSBURGH 22, PENNSYLVANIA

Statements and opinions given in articles and papers appearing in "Iron and Steel Engineer" are the expression of contributors, for which the Association of Iron and Steel Engineers assumes no responsibility.

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Indexed by Engineering Index and by Industrial Arts Index.

Single Copy Foreign Prepaid $2.00 Single Copy $1.50
Subscription price in U. S. and Canada (U. S. funds).....$ 7.50 per year
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TECHNICAL ASPECTS OF NORTHERN AND SOUTHERN BLAST FURNACE PRACTICE

. . . . much can be learned about blast furnace operation by evaluating the differences in northern and southern blast furnace practice . . . .

By C. G. HOGBERG
Assistant to Chairman Blast Furnace Committee
United States Steel Corporation of Delaware
Pittsburgh, Pa.

▲ IT has been said that there are more than fifty variables with which the operator of the iron blast furnace must contend in the process of winning the metal product from its ores. These variables range in importance from relatively inconsequential factors, such as a change in phosphorus content of coke, to items of a serious nature which have a major influence on the final success of the operation both from a physical and an economic standpoint. Ranking high in the latter group is the variable of slag volume, a factor which is governed largely by the iron content or purity of the ores used. The quantity of slag which must be smelted for every unit of iron produced is a major determinant of the quantity of coke which will be consumed and, accordingly, directly effects the productivity of the furnace and consequently its size and financial investment for a given production rate.

The phenomenal rise in the cost of coal during the last few years will alone serve to illustrate the need for an accurate determination of the effect of slag.

The question of slag volume has recently assumed new importance because of the consideration of taconite concentrates and high-grade imported ores. The choice between these materials and high-silica direct shipping domestic ores must be in part determined by application of a factor designed to express the equivalence between slag and the coke required to smelt slag. When confronted with this problem, the metallurgical engineer faces a bewildering array of available factors, ranging from a ratio of 0.2 of a pound of coke per pound of additional slag, and up.

To assist in our attempt to throw some light on the problem, a comparison of blast furnaces employing widely different slag volume practice is the most logical source of data. Such a comparison is made possible by the inherent major difference in iron ores mined for consumption in the Birmingham district when compared with ores from the Lake Superior district, which latter ores comprise the major source of metallics for blast furnaces in the north. For instance, ores mined in Red Mountain in Birmingham contain about 36 per cent iron compared with 50 per cent iron in the northern ores. However, a comparison on the basis of iron content alone is untenable, for the Birmingham ores contain a high proportion of basic flux, while this material is almost absent in northern ores. To facilitate the comparison, data representatives of northern plants have been selected from a three-month test at Edgar Thomson works, Carnegie-Illinois Steel Corp., Braddock, Pa., during which time, results with ordinary mine-run fine Mesabi ores used exclusively on one modern 27-foot 6-inch hearth diameter blast furnace were compared with the results obtained from the use of sized and sintered Mesabi ores on an identical furnace. To represent southern practice, we have selected operating data from a 27-foot 3-inch hearth diameter blast furnace at Fairfield Works, Tennessee Coal, Iron & Railroad Co., Fairfield, Ala., which is supplied exclusively with sized and sintered ores.

DESIGN OF FURNACES

A comparison of the principal dimensions for each of these furnaces appears in Table I and lines of each furnace are shown in Figure 1. It will be noted that while the hearth diameter of Fairfield No. 7 blast furnace is 3 inches smaller than the Edgar Thomson units, the working volume of the Fairfield furnace is greater by 4,233 cubic feet, or 9.5 per cent, which, of course, results in a distinctly higher ratio of working volume to hearth area for the southern unit. Incidentally, in cubical content, Fairfield No. 7 blast furnace is, as far as we are aware, the largest blast furnace in the world, and its successful operation on southern ores of inferior chemical quality is something of which the Birmingham district can well be proud.

Figure 1 — The governing outline dimension of the furnaces compared are given in these sketches. Note that the southern furnace has the larger volume, although it has the smaller hearth diameter.

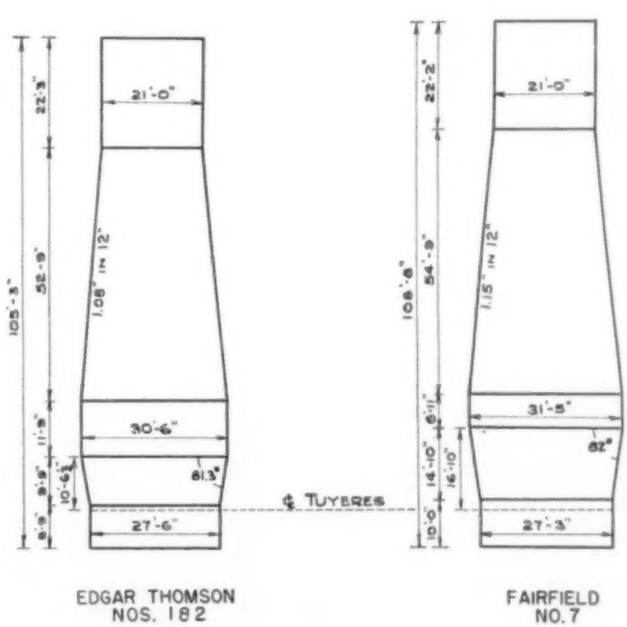

TABLE I

Comparison of Principal Furnace Dimensions

	Edgar Thomson No. 1 and 2	Fairfield No. 7
Hearth diam, ft-in.	27-6	27-3
Bosh diam, ft-in.	30-6	31-5
Stockline diam, ft-in.	21-0	21-0
Large bell diam, ft-in.	15-5	15-0
Total height, ft-in.	105-3	108-8
Working height (Centerline of tuyeres to 6 ft below large bell closed), ft-in.	79-6	86-0
Total volume, cu ft	51,654	55,836
Working volume, cu ft	44,849	49,092
Ratio: Working volume hearth area	75.5	84.2
Bosh angle, degrees	81.3	82.0
Inwall batter, in. per ft	1.08	1.16
No. of tuyeres	18	21

COMPARISON OF ORES

Ores used at all Tennessee Coal, Iron & Railroad Company furnaces are conditioned at a central plant erected for that purpose on Red Mountain in 1940. This plant includes crushing, screening and agglomerating facilities. The ores are separated into two sizes for charging direct; 1½ in. by $^{13}/_{16}$ in. comprising the coarse fraction and $^{13}/_{16}$ in. by ⅜ in. comprising the medium fraction. The minus ⅜ in. fines are sintered in continuous type down-draft machines. The plant includes an extensive silo arrangement whereby the ores are blended to yield a uniform chemical analysis. During the operating period involved herein, the composite ore mixture included 6.2 per cent brown ore, 4.2 per cent Swedish ore, 1.9 per cent Brazilian ore and 87.7 per cent ore from Red Mountain. The brown and foreign ores were crushed, screened, sized, and blended with the regular red ore, and the fines from the foreign and brown ores were likewise sintered along with the red ore fines. The net result of the use of the brown and foreign ores in the red ore mix was an increase in metallics content of the conditioned ores from a normal of approximately 37.4 per cent to 39.7 per cent.

During the test at Edgar Thomson Works, Mesabi ore was screened over a combination of ⅜ in. and ½ in. openings, the fines sintered on a continuous down-draft type of machine before shipment, and the coarse fractions shipped direct. In addition, a coarse-type washed concentrate was used as a slagmaking constituent in the prepared ore burden. Normal ores used in the control burden in the test consisted of ordinary grades from the Mesabi Range.

Comparative chemical analyses of the various composite ore mixtures appear in Table II. Screen analyses are shown in Table III. It will be noted from Table III that the theoretical fines content of the prepared ore burden as expressed in pounds of minus 40-mesh ore charged per ton of hot metal, is 400 lb at Edgar Thomson, as compared with 200 lb at Fairfield. However, the flue dust produced at Edgar Thomson, despite the higher fines content, is 227 lb per net ton of hot metal, or about 25 per cent less than the 292 lb of flue dust produced per ton of iron at Fairfield. The relatively high fines content of the Edgar Thomson prepared ore

TABLE II

Chemical Analysis and Density of Composite Ore Burdens

	Edgar Thomson		Fairfield per cent
	Regular per cent	Prepared per cent	
Natural Fe	50.23	56.58	39.31
Phos	0.051	0.053	0.33
Mn	0.63	0.40	0.18
SiO_2	7.59	5.52	14.49
Al_2O_3	1.51	1.25	2.86
CaO	0.09	0.08	12.54
MgO	0.08	0.06	0.71
Moisture	12.94	7.92	3.00
Fe (dry basis)	57.70	61.45	40.53
Estimated lb/cu ft	123.2	141.3	112.6

TABLE III

Screen Analysis of Composite Ore Burdens

	Edgar Thomson		Fairfield per cent
	Regular per cent	Prepared per cent	
On ½ in.	28.8	47.6	69.0
Through ½ in.—On ⅛ in.	23.7	24.8	20.0
Through ⅛ in.—On 20 mesh	12.6	9.6	4.7
Through 20 Mesh—On 40 Mesh	7.7	4.5	2.0
Through 40 Mesh	27.2	13.5	4.3
Lb natural ore/net ton hot metal	3671	3221	4807
Lb dry ore/net ton hot metal	3196	2966	4662
Lb minus 40-mesh ore charged /net ton hot metal	869	400	200
Lb total flue dust produced /net ton hot metal	284	227	292

TABLE IV

Comparative Burdens

	Lb per net ton hot metal		
	Edgar Thomson		Fairfield
	Normal	Prepared	
Group 3 Mesabi	2748	....	....
Group 7 Mesabi	923	....	....
Group 3 coarse	....	1637	....
Group 7 concentrates	....	939	....
Group 3 sinter	....	645	....
Conditioned—coarse	....	....	2776
Conditioned—medium	....	....	778
Conditioned—sinter	....	....	1253
Total ores	3671	3221	4807
Excess scrap charged (100 per cent metallics)	21	20	118
Scale	....	1	....
Open hearth slag	395	363	....
Converter cinder	1	2	....
Gravel	26	30	....
Total miscellaneous materials	448	421	118
Limestone	811	544	....
Dolomite	196	133	803
Total flux	1007	677	803

burden is the result of inefficient screening, i. e., the adherence of fines to the coarse material passing over the screen.

Although the data on furnace operation for the prepared ore burdens in each case are the most comparable available, it should be borne in mind that any conclusions later drawn should be tempered by the recognition that the burdens are not strictly identical from a size standpoint.

EFFECT OF SCRAP AND FLUX

A detailed comparison of burdens is shown in Table IV; Table V includes the chemical analysis of miscellaneous burden materials. It will be noted from Table IV that the Fairfield burden contains 118 lb of metallics in scrap per net ton of iron compared with 20 lb per ton for the sized burden at Edgar Thomson. The effect of this, together with the effect of flux and moisture in ores, narrows the disparity between ore burdens as is indicated on Table VI. For instance, the dry metallics analysis of ores in the prepared burden is 62 per cent at Edgar Thomson, compared with 41 per cent at Fairfield, a spread of 21 per cent. However, on the basis of the total metallic mixture, including flux, the Edgar Thomson dry metallics content of 49 per cent compares with the figure of 37 per cent for Fairfield, a spread of only 12 per cent.

OPERATING RESULTS

Comparative practice data are shown on Table VII. Considering only the prepared ore burdens, the most impressive difference, apart from slag volume, is the relatively high blast rate for Fairfield, with its 97,697 cfm, equivalent to 168 cfm per sq ft hearth area, compared with the Edgar Thomson figure of 144 cfm per sq ft of hearth area. The high blast rate at Fairfield, which is typical of Birmingham practice, makes possible the hot metal production rate of 1268 tons per day with a coke rate of 2170 pounds, compared with a 1605 tons daily production rate at Edgar Thomson Works accompanied by a coke rate of 1510 pounds. The high blast rate on the Fairfield furnace would be impossible to attain without the use of ores conditioned to promote uniformity and to insure freedom from excessive fines. Despite this high rate, however, the Fairfield furnace produced per unit of volume only 72 per cent of the iron produced in the Edgar Thomson furnace.

It will be noted that over a ton of slag was produced per ton of hot metal in the Fairfield practice and that more than twice as much slag was produced at Fairfield than at Edgar Thomson. This is, of course, the primary cause of the increase in coke rate at Fairfield. Its effect will be dealt with in detail later.

TABLE V

Natural Chemical Analysis and Density of Miscellaneous Burden Materials

	% Fe	% Phos	% Mn	% SiO_2	% Al_2O_3	% CaO	% MgO	% Ultimate carbon	Moisture	Lb/cu ft
Edgar Thomson:										
Open hearth slag	26.57	0.950	6.71	18.15	3.78	23.66	5.87	.....	1.64	150
Gravel	2.30	0.051	0.09	81.74	5.68	1.55	0.48	.....	3.23	100
Limestone	0.80	0.036	0.09	3.46	0.50	50.86	0.98	.....	0.85	100
Dolomite	0.49	0.008	0.07	1.06	0.20	30.80	20.04	.....	1.04	100
Scrap	74.18	0.119	1.05	9.07	.....	.....	.....	.....	.....	200
Coke*	0.97	0.011	0.01	5.28	3.07	0.38	0.09	84.06	2.50	300
Fairfield:										
Dolomite	0.16	.....	.....	1.23	0.58	31.13	19.94	.....	1.25	100
Scrap	91.91	0.140	0.41	2.17	0.24	3.31	0.61	.....	.....	200
Coke*	0.91	0.025	.....	4.71	3.58	0.42	0.10	85.35	2.50	34

*Coke analysis calculated to 2½ per cent moisture basis for comparative purposes. Actual moisture in coke was:
Edgar Thomson — 2.03 per cent
Fairfield — 3.80 per cent

TABLE VI

Metallics Content of Burdens

	Edgar Thomson		Fairfield
	Normal	Prepared	
Natural basis (per cent):			
Ore (including sinter)	50.91	57.03	39.82
Ore and scrap	51.26	57.36	41.30
Ore, scrap, misc and flux (including flue dust)	39.79	46.15	35.56
Ore, scrap, misc and flux (less flue dust)	39.08	45.76	35.97
Dry basis (per cent):			
Ore (including sinter)	58.48	61.93	41.05
Ore and scrap	58.81	62.25	42.54
Ore, scrap, misc and flux (including flue dust)	44.00	49.21	36.53
Ore, scrap, misc and flux (less flue dust)	43.49	48.97	37.02

TABLE VII

Comparative Practice Results

	Edgar Thomson		Fairfield prepared	Difference in prepared burdens	
	Normal	Prepared		Amount	Per cent
Hot metal production — net tons/day:					
Actual	1,305	1,580	1,261	.....	.....
Adjusted for delays	1,324	1,605	1,268	— 337	— 21.0
Adjusted hot metal production:					
Net tons/day/sq ft hearth area	2.23	2.70	2.17	— 0.53	— 19.6
Net tons/day/100 cu ft working volume	2.95	3.58	2.58	— 1.00	— 27.9
Net coke consumption rate, lb/net tons hot metal	1,782	1,510	2,170	+ 660	+ 43.7
Net carbon rate	1,498	1,266	1,852	+ 586	+ 46.3
Flue dust and sludge recovered, lb/net tons hot metal	284	227	292	+ 65	.....
Average per cent silicon in hot metal	0.91	0.87	0.80	— 0.07	.....
Average per cent sulphur in hot metal	0.030	0.030	0.047	+ 0.017	.....
Hot metal over 0.050 per cent sulphur, per cent	1.2	0.3	27.5	+ 27.2	.....
Slag analysis (per cent) SiO_2	34.9	34.8	37.5	.....	.....
Al_2O_3	12.3	12.8	9.6	.....	.....
CaO	46.0	45.6	40.0	.....	.....
MgO	3.7	3.8	10.1	.....	.....
Sul	2.0	2.1	1.1	.....	.....
Ratio: Bases/acids	1.05	1.04	1.06	+ 0.02	.....
Bases/silica	1.42	1.42	1.33	— 0.09	.....
Calculated slag volume, lb/net ton hot metal	1,264	968	2,040	+ 1,072	+110.7
Air blast at furnace (30 in. Hg—60 F):					
Total cu ft/minute	83,446	85,366	97,697	+12,331	+ 14.4
Cfm per sq ft hearth area	140.5	143.7	167.5	+ 23.8	+ 16.6
Blast temperature, F	969	916	932	+ 16	.....
Blast pressure at furnace, psi	20	22	27.5	+ 5.5	.....
Top temperature, F	356	323	370	+ 47	.....
Water added to charge, lb/net ton hot metal	151	92	111	+ 19	.....

The 5½ lb increase in blast pressure at Fairfield is the result of the combined effect of higher slag volume and higher blast rate. The higher magnesia content at Fairfield probably minimizes the true effect of excessive slag volume, particularly in the lower sections of the furnace. However, the desulphurizing power of this slag was unfavorably influenced by higher magnesia, as indicated by the lower sulphur content of slag and the higher sulphur content of iron in the Fairfield practice.

As shown in Table VIII, a ratio of 3.23 CO to CO_2 in the top gas at Fairfield compares with the ratio of 2.11 for the prepared ore burden at Edgar Thomson; this reflects both the higher gas velocity at Fairfield and the relatively greater necessity in Southern practice to provide carbon to fulfill the heat requirements of slag, rather than for reduction of iron oxide. Despite the higher gas velocity at Fairfield, the top gas temperature of 370 F was relatively low considering that only moderate amounts of moisture and added water were present in the burden. This reflects the influence of the generous working volume afforded by the Fairfield furnace design.

Theoretical residence time and travel rate of stock are calculated by the application of representative densities as determined by stockhouse samples, and appear in Table IX. It is to be understood that the results of this calculation are relative only, since it does not consider the possible effects of mixing of various burden constituents, nor does it recognize the change in burden volume as a result of fusion or decrepitation. Nevertheless, the results serve to indicate that the higher coke rate together with a less dense ore required in Fairfield practice has the effect of decreasing the holding capacity of the furnace. The theoretical decrease is 116 tons of equivalent hot metal, or 21 per cent, despite the 10 per cent increase in cubical content of the furnace.

Tables X and XI reveal details on heat generation and utilization. It is of interest to note that the efficiency of utilization of fuel carbon in the furnace decreases from 49 per cent for the prepared burden at Edgar Thomson to 39 per cent at Fairfield. These efficiency data do not comprehend the utilization of the calorific heat in the top gas for purposes other than the heating of the blast, since they are intended to reflect only the efficiency of the furnace as a metallurgical processing unit. It will be understood that a certain loss in efficiency is unavoidable because of equilibrium requirements in the carbon/iron oxide system.

HEAT DEVELOPED IN HEARTH

An unexpected revelation is that about the same proportion of carbon was gasified at the tuyeres in the Fairfield practice as at Edgar Thomson, this amount being calculated to be 89.4 per cent of the total fuel carbon gasified in the furnace, compared with 89 per cent for the prepared ore burden at Edgar Thomson. Details appear in Table XII.

Table XII also shows a calculation of the heat generated in the hearth, which method has been recom-

TABLE VIII

Air Blast and Top Gas Data

	Edgar Thomson		Fairfield
	Normal	Prepared	Prepared
Air blown, standard, cfm	83,446	85,366	97,697
Air blown, standard, cfm/ton iron	90,817	76,583	110,949
Carbon in coke, lb/ton iron	1,498	1,266	1,852
Cu ft blast air/lb carbon in coke	60.6	60.5	59.9
Moisture in blast, grains/cu ft	2.30	2.30	6.06
Blast temperature, F	969	916	932
Heat in blast, Btu/ton iron	1,620,000	1,291,000	2,005,000
Dry top gases, cu ft/ton iron	121,435	100,636	148,365
Analysis of dry top gas, per cent by volume:			
CO	26.57	26.17	30.70
CO_2	12.33	12.40	9.50
H_2	2.30	1.60	1.60
CH_4	0.13	0.13	0.20
N_2	58.67	59.70	58.00
Total	100.00	100.00	100.00
Ratio CO/CO_2	2.15	2.11	3.23
Gross calorific value, Btu/cu ft	94.3	90.7	105.9
Gross calorific value, Btu/ton iron	11,546,000	9,223,000	15,712,000
Weight of total top gas:			
Lb/ton iron			
CO	2,407	1,969	3,370
CO_2	1,755	1,466	1,639
H_2	15	9	13
CH_4	7	6	13
N_2	5,315	4,492	6,368
Water vapor (calculated)	791	474	339
Total	10,290	8,416	11,742
Volume of total top gas, cu ft/ton iron	139,065	111,653	155,492
Volume of total top gas, cfm	127,863	124,447	136,800
Top gas temperature — F	356	323	370
Sensible heat in top gas, Btu/ton iron	935,000	677,000	1,118,000

TABLE IX

Calculated Residence Time and Travel Rate of Burden

	Edgar Thomson		Fairfield
	Normal	Prepared	
Cu ft material/net tons hot metal:			
Ore plus sinter	29.8	22.8	42.7
Open hearth slag	2.6	2.4	.....
Scrap	0.1	0.1	0.7
Flux and misc	10.2	7.1	8.0
Coke	59.4	50.3	63.8
Gross total	102.1	82.7	115.2
Less flue dust	—2.6	—2.1	—4.2
Net total	99.5	80.6	111.0
Production, net tons hot metal/day	1,324	1,605	1,268
Cu ft materials processed/day	131,738	129,363	140,748
Working volume, cu ft	44,849	44,849	49,092
No. of furnace fillings per day	2.94	2.88	2.87
Theoretical residence time, hr	8.2	8.3	8.4
Working height, ft	79.52	79.52	86.00
Theoretical stock descent rate, ft/hr	9.7	9.5	10.3
Iron processed/filling, net tons	450	557	441

TABLE X

Generation of Heat

	Edgar Thomson		Fairfield
	Normal	Prepared	Prepared
Carbon in top gases, lb/net ton hot metal:			
In carbon monoxide	1,024	838	1,444
In total carbon dioxide	475	397	447
Less carbon in flux and ore carbonates	113	76	198
Net carbon gasified to carbon dioxide	362	321	249
Theoretical heat generated in furnace, million Btu:			
From gasification of carbon to carbon monoxide	4.513	3.693	6.364
From gasification of carbon to carbon dioxide	5.267	4.671	3.623
Plus heat from hot blast	1.620	1.291	2.005
Total heat input, million Btu	11.400	9.655	11.992
Less sensible heat in top gas, million Btu	0.935	0.677	1.118
Net heat absorbed in process, million Btu	10.465	8.978	10.874
Lb. dry top gas/net tons hot metal	9,499	7,942	11,403
Equivalent process heat/lb dry top gas, Btu	1,102	1,130	954

TABLE XI

Efficiency of Utilization of Fuel Carbon in Furnace

	Edgar Thomson		Fairfield
	Normal	Prepared	Prepared
Total lb fuel carbon gasified in furnace, lb	1,386	1,159	1,693
Theoretical total heat available per lb carbon — Btu	14,550	14,550	14,550
Total calorific heat in top gases, million Btu	11.546	9.223	15.712
Total sensible heat in top gases, million Btu	0.935	0.677	1.118
Total heat lost in top gases, million Btu	12.481	9.900	16.830
Total heat lost Btu/lb fuel carbon gasified	9,005	8,541	9,941
Less heat in blast, million Btu/net ton hot metal	1.620	1.291	2.005
Less heat in blast, Btu/lb fuel carbon gasified	1,169	1,114	1,121
Net heat lost in top gas, Btu/lb fuel carbon	7,836	7,427	5,820
Net heat utilized in furnace, Btu/lb fuel carbon	6,713	7,123	8,730
Net heat utilized in furnace, per cent of available heat	46.1	49.0	39.4

mended by Joseph as a more realistic approach in demonstrating the importance of heat derived from the blast. The blast heat contributes almost 25 per cent of the net hearth heat in the Fairfield practice and slightly less than this amount at Edgar Thomson. Of perhaps greater significance, this table shows that 6.8 per cent of the net hearth heat was required for dissociation of blast moisture at Fairfield compared with 2.6 per cent at Edgar Thomson. The higher proportion of hearth heat required for dissociation of blast moisture in Southern practice is the combined effect of inherently higher humidity together with higher blast air requirements as a result of higher coke rate.

EFFECT OF SLAG ON FUEL CONSUMPTION

The apparent increase in carbon rate at Fairfield is equivalent to 54.7 lb of carbon per 100 lb additional slag, as summarized in Table XIII. Since the Fairfield furnace was operated at a higher blast humidity and since the working volume to hearth area ratio is higher at Fairfield than at Edgar Thomson, adjustment must be made for these differences. We have calculated the effect of blast moisture to be unfavorable to Fairfield to the extent of 78 lb of carbon per ton of hot metal. The effect of increased furnace volume is estimated to be favorable to the extent of 35 lb of carbon, as derived from a graph shown in the author's previously published paper on furnace design. The net adjusted difference in carbon rate then becomes equivalent to 50.7 lb of carbon or 60.3 lb of typical coke per 100 lb of slag.

In the calculation of the foregoing figures, no allowance is made for increased scrap consumption at Fairfield since it can be assumed that the carbon monoxide in the top gas at Fairfield is already so far in excess of reduction requirements that more ore could be readily reduced than needed, if the scrap were replaced by ore. In other words, the carbon requirements are in a range where the carbon necessary for reduction purposes only has long since been satisfied and carbon required to generate heat for melting is of primary importance. As an illustration of this in contrast with Northern furnace practice, we can cite the investigations of Kin-

TABLE XII

Carbon Burned and Heat Generated at Tuyeres

	Edgar Thomson		Fairfield
	Normal	Prepared	Prepared
Fuel carbon gasified in furnace, lb/net ton hot metal	1,386	1,159	1,693
Air blast, lb/net ton hot metal	6,910	5,820	8,390
Per cent total oxygen in air	23.65	23.65	24.07
Oxygen, lb/net ton hot metal	1,634	1,376	2,019
Lb carbon burned at tuyeres/lb blast oxygen	0.75	0.75	0.75
Lb carbon burned at tuyeres/net ton hot metal	1,226	1,032	1,514
Per cent carbon gasified at tuyeres	88.5	89.0	89.4
Blast rate, cfm/net ton hot metal	90,817	76,583	110,949
Moisture in blast, grains/cu ft	2.30	2.30	6.06
Moisture in blast, lb/net ton hot metal	29.84	25.16	96.05
Heat required to dissociate blast moisture at 5774 Btu/lb — Btu	172,300	145,200	554,500
Development of heat at tuyeres — million Btu/net ton hot metal			
Heat from carbon gasified to carbon monoxide	5.400	4.546	6.669
Plus heat in blast	1.620	1.291	2.005
Less heat required for dissociation of blast moisture	—0.172	—0.145	—0.554
Net total heat at tuyeres — million Btu	6.848	5.692	8.120
Per cent of hearth heat in hot blast	23.7	22.7	24.7
Per cent of hearth heat required for moisture dissociation	2.5	2.6	6.8

ney, which established that in the Southern furnace, 80 per cent of the ore was reduced at the top of the bosh compared with only 24 per cent for a furnace burdened with Mesabi ore. This is not surprising when it is realized that for any similar level above the bosh, the reduction potential of gas in the Southern furnace is much higher than on the Northern furnace.

DESCENT OF FURNACE STOCK

A pronounced feature of Southern blast furnace operation is that, unlike conventional Northern practice, the furnace stock does not descend without regular "checking" of the blast, which is accomplished by reducing the blast pressure through diversion of part of the air blast through a "snort" valve to the atmosphere. This is done about once every twenty minutes, and the interval of blast reduction is usually less than a minute.

Northern operators have generally looked askance at this practice, giving one the impression that it carries a certain stigma and that it is something to be avoided. However, we cannot refrain from suggesting that some Northern operators would gladly abandon their scruples about this practice if, through its adoption, they could successfully carry as high a blast rate as their Southern contemporaries. On the other hand, it is perhaps relevant to express the opinion that the Southern operator has been needlessly apologetic about this feature of his operation and has unnecessarily placed himself on the psychological defensive. Before concentrating on the real objective of this discussion, it might be appropriate to point out that the main deterrent to the adoption in the North of the extremely high blast rate practice of the South would appear to be the greater sensitivity of Northern furnaces to channelling of gas and irregular movement of stock as a result of application of high blast rates under their conditions of excessive fines in the ore burden and lower coke rate. The sole exception to this is the possible

TABLE XIII

Calculation of Fuel Carbon Required for Slag

	Edgar Thomson Prepared	Fairfield Prepared	Difference
Carbon rate, lb/net ton hot metal	1266	1852	586
Slag volume, lb/net ton hot metal	968	2040	1072
Apparent increase in carbon rate per 100 lb increase in slag			54.7
Less allowance for moisture in blast			—78
Plus allowance for increased furnace volume			+35
Net adjusted difference in carbon rate			543
Adjusted difference: lb carbon/100 lb slag			50.7
Adjusted difference: Lb coke/100 lb slag at 84 per cent carbon in coke			60.3

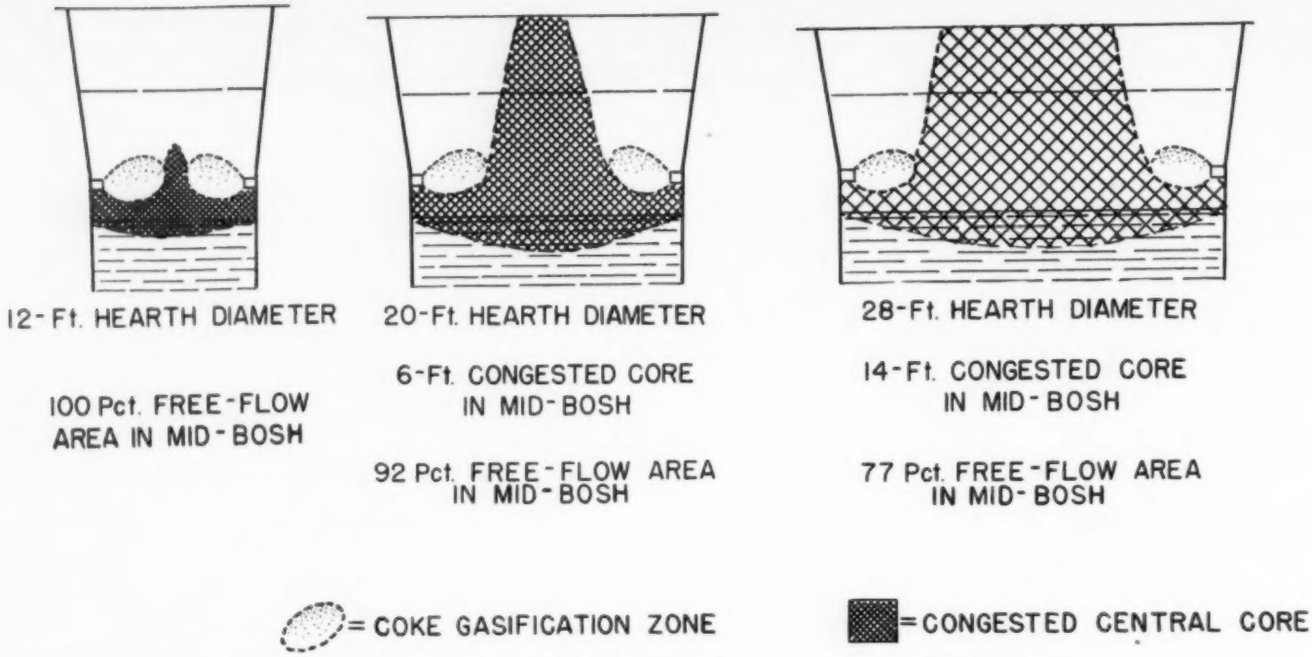
12-Ft. HEARTH DIAMETER
100 Pct. FREE-FLOW AREA IN MID-BOSH
20-Ft. HEARTH DIAMETER
6-Ft. CONGESTED CORE IN MID-BOSH
92 Pct. FREE-FLOW AREA IN MID-BOSH
28-Ft. HEARTH DIAMETER
14-Ft. CONGESTED CORE IN MID-BOSH
77 Pct. FREE-FLOW AREA IN MID-BOSH
= COKE GASIFICATION ZONE
=CONGESTED CENTRAL CORE

Figure 2 — The sketches show how the theoretical areas of free stock flow are influenced by furnace size.

beneficial effect of elevated top pressure in conjunction with fine ore practice.

Why does the Southern furnace hang? Perhaps a more appropriate question would be: "Why does any furnace hang?" There are, no doubt a number of reasons for hanging but an elementary review of only the probable major causes may be enlightening. We can start with the trite but logical assumption that the stock in the furnace fails to descend freely either because it is suspended by the energy of the ascending gases or because its descent is mechanically blocked by material that is too viscous to flow freely and consequently bridges, or arches, over the path of descent. The latter condition is probably aided in many instances by bosh scabs of either limey primary slags or ore and coke fines.

It is pertinent to mention at this time that ores in the Birmingham district melt at a markedly lower temperature than do Northern ores, as indicated in Table XIV. This difference in temperature is probably in the order of 500 F, as determined from the ternary diagram of the SiO_2-Al_2O_3-CaO system, and checked within reason from laboratory tests reported by J. J. Howard. The relatively low density of the stock column, together with the large volume of slag in Southern practice and the presumably increased depth over which voids in ore trend to disappear due to the increased intimacy of contact and softening of the ore as its gangue melts, would appear to offer ample reason for the tendency of the Southern furnace to hang.

In discussing this subject at a meeting of the Association of Iron and Steel Engineers in Birmingham in 1939, J. E. Urquhart quoted G. M. Harris in a statement to the effect that in his experience only Southern furnaces in excess of about 14 feet hearth diameter failed to move freely. We believe this statement offers a clue to the problem of stock descent in general, when it is considered in the light of our knowledge of combustion in front of the tuyeres and of stock flow within the furnace as determined by the classic investigation of Kinney and others.

Surveys of the combustion zone at tuyere level have

TABLE XIV

Relative Melting Points of Ores

	Theoretical from ternary slag diagram		J. J. Howard laboratory test	
	Edgar Thomson prepared	Fairfield prepared	Typical Mesabi	Typical Southern
Analysis of slag oxides in ore (less flue dust)				
SiO_2 (per cent)	5.21	14.83	5.18	12.64
Al_2O_3 (per cent)	1.17	2.87	1.00	.....
CaO (per cent)	.....	12.97	0.21	16.52
MgO (per cent)	.....	0.30	0.11	0.16
Total	6.38	30.97	6.40	29.32
Melting point, F	3110	2604	2795	2260
Decrease in melting point of Southern ore	.....	506	.....	535

shown that the area of gasification of coke extends only about 4 ft in front of the nose of the tuyere, regardless of furnace size. As illustrated on Figure 2, these zones on a small furnace are almost contiguous across the hearth and we can expect that the stock movement above the hearth in a small furnace would be fairly uniform across any plane. However, as the furnace size increases, the combustion zone in front of the tuyere begins to resemble in cross-section the apex of a funnel, with one side of the funnel formed by the bosh and the opposite side by a wall of congested or relatively immobile stock. Circumstantial evidence of the presence of this central core is obtained from the reported investigations of stock flow by Joseph, Royster, and Kinney, and more recently from high-speed motion pictures taken through blast furnace tuyeres at both Edgar Thomson and Fairfield Works.

With the central core as conceived and illustrated on Figure 2, the area of free stock flow at a plane midway up the bosh decreases from 100 per cent in a 12-ft hearth diameter furnace to 92 per cent in a 20-ft furnace and 77 per cent in a 28-ft furnace. The central core probably acts as a more or less fixed wedge which, because of its inverted keystone shape, serves as a conical abutment for the bridging action of stock in the active periphery when conditions are conducive to such bridging. With this concept, it is not difficult to understand why a 28-ft hearth diameter blast furnace can hang as readily as a 20-ft furnace, why an adequate number of tuyeres are necessary to avoid a scalloped periphery in the free-flow annulus, and why a difference of a degree or two in bosh angle and a few feet in bosh height loom as matters of real consequence. In addition, the necessity for operating a furnace with a bosh wall coating of moderate and uniform thickness emerges as a factor of considerable significance. Incidentally, it can be calculated that a 12-in. coating on the bosh of the 20-ft hearth diameter furnace shown on Figure 2 reduces the theoretical area of free stock flow at a plane across the middle of the bosh from 92 per cent to 75 per cent.

We can draw on observations of rotary kiln operation in further speculation of stock flow in the bosh area, with particular reference to rotary kilns used to nodulize Mesabi ore fines as has been practiced for almost ten years at a large cement plant near Pittsburgh. This operation is characterized by the formation of a continuous "ring" or coating on the interior lining of the kiln over a distance of about 20 ft from the hot end of a unit having a total length of 120 ft. We have personally observed at this plant the formation of a ring 2 ft in thickness within about 20 minutes time. The basic factor governing ring formation in the rotary kiln appears to be one involving the temperature difference between the brick lining and the material passing over it. Hot, viscous material will adhere readily to a relatively cold lining, and vice versa. Fine materials adhere much more readily than do coarse materials. The tendency toward adherence is aggravated by an unfavorable chemical analysis of the slag formed from the gangue in the ore, resulting in an improper range of incipient fusibility and viscosity of the slag. Uniformity of feed both as regards size and chemical analysis, and controlled combustion are the sine qua non of successful rotary kiln operation. Modern rotary kiln design employs the use of water cooled boring-bar type of scraper to control the formation of rings.

The analogy between the formation of rings in a rotary kiln and the tendency to form scabs in the bosh of a blast furnace is apparent. Excessive bosh build-up is generally manifest in Southern operations by failure of the stock to move freely after a normal blast check. At Northern plants, where accumulations on the bosh seem to be more prevalent and where highly basic final slags must be carried to meet rigid sulphur specifications of hot metal, the signs of excessive bosh coating are also evidenced by irregular stock movement and a tendency toward rolling and blowing through. Limey primary slag which must be carried due to high ash in coke is also a deterrent to smooth stock movement in the bosh. The absence of gas issuing through joints in the area of the upper bosh is sometimes indirect evidence of bosh accumulation, although this provides no indication of the extent of the coating.

While the blast furnace operator cannot use a boring-bar, he does have at his disposal several means of controlling the formation of bosh coating. These measures vary widely. Use of tuyeres of shorter length and increased diameter; reversing the sequence of the charging cycle; use of siliceous material such as gravel and converter slag; heavy charges of scrap; and coke blanks, are all reported to be effective. The use of coke blanks for this purpose is favored at one plant in the Pittsburgh district, where it has been found that these blanks do an effective job of cleaning the bosh when used twice a week per furnace; it is of more than passing interest that coke blanks so used do not result in the production of high-silicon iron. Presumably, the heat required to melt the accumulation as it is scoured off the bosh by the action of the highly permeable coke blank is provided by the heat made available by the additional coke.

The use of siliceous "cleaners" is usually accompanied by a gradual "leaning out" or increased acidity of the slag, with consequently higher sulphur in the iron. This temporary inconvenience, however, does not begin to compare with the havoc brought about as a result of a sudden "peeling" of a bosh scab due to the sheer weight of an uncontrolled accumulation. It can be readily calculated that a 12-in. thick scab formed over the 10 ft 3 in. height of bosh on a 28-ft hearth diameter furnace will have a volume of 918 cu ft. With a density conservatively estimated at 140 lb per cu ft, the scab will have a total weight of about 64 tons. If it is assumed that the scab has an average temperature of 1000 F (a gradient of 100 F next to the bosh plates to 2100 F at the hot face) and if it is further assumed that only half of this scab falls into the hearth, it can be determined that about 45 million Btu will be required to raise the temperature of the scab to the nominal slag temperature of 2900 F. If the furnace is producing iron at a rate of one ton per minute, and the heat required to raise the scab to hearth temperature is to be transferred within one hour, it can be calculated that the hearth gas temperature will decrease 130 F, the slag temperature will decrease 150 F, and the hot metal temperature will decrease 140 F during this period. This assumes that one-half of the heat required

TABLE XV

Calculated Effect of Fallen Bosh Scab on Hearth Temperature

	Assumed scab density	
	180 lb/cu ft	140 lb/cu ft
Calculated total volume of 12-in. scab, cu ft	918	918
Total weight, net tons	82.6	64.3
Assumed average temperature of scab in place, F	1,000	1,000
Assumed weight scab dropped into hearth, net tons	41.3	32.2
Net heat required to raise scab to 2900 F, Btu	57,669,000	44,853,000
Calculated effect of heat withdrawal from hearth (F)		
Hearth gas temperature:		
Normal	2,950	2,950
1 hr after scab drop	2,785	2,820
Decrease	165	130
Slag temperature:		
Normal	2,900	2,900
1 hr after scab drop	2,714	2,750
Decrease	186	150
Hot metal temperature:		
Normal	2,800	2,800
1 hr after scab drop	2,624	2,660
Decrease	176	140

will be extracted from the hearth gases and one-half from the slag and iron. If the scab has a higher density, the temperature drop will be more severe, as shown on Table XV. Moreover, if the scab contains a large amount of iron oxide, the endothermic effect as a result of direct reduction in the hearth will bring about a still higher heat extraction.

While the unfavorable temperature effect as a result of a falling scab is in itself serious enough, it does not compare with the results which ensue in the disturbance of gas flow and stock movement. The drop in temperature of the rising gases will immediately solidify primary bosh slags of marginal viscosity and transform already fluid slags into a gummy mass. This will result in bridging over of the stock and a decrease in the gas permeability of the burden above the area of scab fall. A greater volume of gases is then concentrated on the side of the furnace where the scab is intact, but the rapidly dropping gas temperature soon brings about a similar sequence of events on this side of the furnace, although possibly not as serious. The net effect is a complete disruption of the normal pattern of gas flow and stock flow within the furnace, with resultant increased blast pressure, hanging and slipping of the stock, blocked or sluggish tuyeres, cold and dirty slag, and high-sulphur irons as its outward manifestation. A drastic cut in blast rate and in ore burden, and an increase in blast temperature, if available, are required to bring the furnace back to normal, which objective is not always attained until after several days; indeed, some operators can probably recall in their experience the unscheduled near-termination of an otherwise successful furnace campaign as the result of the sequence of events just described.

PROBLEM OF HIGH BLAST TEMPERATURE

We cannot leave the subject of stock flow in the blast furnace without mention of the problem of high blast temperature, particularly in conjunction with fine Mesabi ores. The general inability to economically apply high blast temperatures when operating with low coke rates in the production of basic iron is probably the result of a sharp increase in basicity of the primary bosh slag due to reduction of more silicon into the iron combined with lowering of the zone of fusion, with subsequent increased blast pressure and irregular stock movement, as postulated in 1914 by Brassert when the low and steep bosh was under development at South Chicago. This is no doubt aggravated by an increase in the differential between the temperature of the bosh lining and the descending stock, resulting in a greater tendency toward scab formation.

The prospect of improved operation with high blast heat as a result of deliberately carrying more acid bosh slags together with yet steeper bosh angles is intriguing, and one which will no doubt assume greater importance as more pressing current problems in raw materials beneficiation approach solution.

EROSION OF FURNACE LININGS

Shortly after going on conditioned ore in 1940, blast furnaces at Tennessee Coal, Iron & Railroad Company began to cut new lines as evidenced by the appearance of hot spots from 15 to 25 ft above the mantle. It became necessary to install stack cooling plates above the mantle in subsequent relinings. However, this permitted the use of thinner linings and increased the working volume, with beneficial results. The tendency toward accelerated lining erosion as a result of the application of coarse ore burdens is not confined solely to the Birmingham district. It is mentioned here only because it is an important factor when considering a large-scale conversion to beneficiated ore practice.

SUMMARY

The principal differences in blast furnace practice between the North and the South are largely brought

about by a major difference in the analysis of iron ore. A typical Mesabi ore will analyze approximately 50 per cent natural iron, compared with about 36 per cent natural iron for ores mined in Red Mountain in the Birmingham district. The fact that Birmingham ores contain fairly large amounts of lime in combination with acid gangue does not justify a comparison on the basis of iron content alone. However, despite the lime content, blast furnace practice in the Birmingham district is characterized by slag volume in excess of 2,000 lb per ton of iron, compared with 800 to 1200 lb in the North.

The high slag burden in Birmingham practice has a marked influence on thermal requirements, and increases the coke consumption rate. This increase in fuel rate appears to be equivalent to 60 lb of typical coke per 100 lb of increased slag. Because of the higher fuel requirement, higher blast rates are necessary for satisfactory iron production performance. These higher blast rates are made possible by sizing of ores through screening and agglomerating the fines. To compensate in part for the higher blast rates and higher fuel requirement in the South, the furnaces must be provided with more generous proportions of working volume relative to hearth area than is required for furnaces in the North.

Free stock descent on Southern blast furnaces less than 14 ft in hearth diameter provides a clue to the pattern of stock flow in the lower area of larger furnaces in both the North and the South. The influence on stock flow of the congested or relatively stationary central core, of bosh angle, and scab accumulations on the bosh emphasizes the importance of controlling the extent of such formations by the judicious use of "cleaners."

Acknowledgment — Thanks are due the following individuals in United States Steel Corporation who either cooperated in providing some of the basic data included in the paper or, by their encouragement and experience, contributed to the development of the discussion on furnace stock descent covered in the last part of the paper: Messrs. C. D. King; A V. Wiebel; H. A. Strain; J. A. Maxwell; W. D. Harris; J. M. Walsh, Jr.; W. R. Trognitz; W. H. Burnett; and William Bennett.

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DISCUSSION

PRESENTED BY

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H. A. Byrns: Mr. Hogberg has clearly and logically pointed out some of the major differences between northern and southern blast furnace practice, and he has, to a large degree, answered many of the questions that always arise when northern and southern operators gather.

In commenting of Mr. Hogberg's paper, our comparison will be based, of necessity, on the practice with which we are most familiar; namely, at the Woodward Iron Co.

Because of the analysis of Red Mountain ore, slag volumes are, and always have been, of paramount importance, we know that pig iron of a given composition always requires a constant quantity of metallic iron, whether that iron is extracted from rich or lean ore. A pig containing 95 per cent metallic iron must have 95 lb of iron in each 100 lb of pig. If the ore is lean, more of it must be used. Disregarding the gangue for the moment, the cost of extracting 95 lb of metallic iron from the ore consists only of the value of the carbon needed to reduce and melt it. It is evident then, that for a given fuel and a given iron analysis, this cost must be constant for each ton of pig, no matter whether the ore be rich or poor. Therefore, the relative values of ores are not affected by the cost of extracting their iron content, but depend entirely on the expense of processing the gangue. This being the case, it can readily be seen that the amount of slag volume is considerable of an economic factor.

We question, for our own information, Mr. Hogberg's figure of 50.7 lb of carbon, fuel requirement per 100 lb of slag. We use 30 lb per 100 lb of slag and obtain reasonably accurate results. Our slags continually fall in Silicate Group 2 or 6 with a viscosity of 5 or 6. At this writing we do not have available McCaffery viscosity diagrams to check Fairfield's slags. Could it be that this high magnesia content required more carbon?

We vary considerably with both Fairfield and Edgar

Thomson as regards furnace design. For example, Edgar Thomson has an annular span between big bell and hopper of 2 ft 9½ in., and a ratio of 1.85 between area of the top and area of big bell. Fairfield has an annular span of 3 ft with a 1.96 ratio. Woodward furnaces all have a 2 ft 9 in. annular span with top ratios of 2.13; 2.19; and 2.25 respectively. These dimensions have been arrived at by our experience over the years.

Large working volumes, as mentioned by Mr. Hogberg, are especially beneficial to any furnace. We have gone farther in that direction than either Edgar Thomson, with a ratio of working volume to hearth area of 75.5, or Fairfield, with a ratio of 84.2. Woodward furnaces have ratios of 99.9 to 1.00; 83.7 to 1.00 and 84.9 to 1.00. On all three furnaces the top diameters are the same as hearth diameters; namely, 17½ ft, 17 ft, and 16½ ft.

With these dimensions we produced during 1949, 2.475 net tons per square foot of hearth area on the large furnace; 2.396 on the second furnace; and 2.318 on the third furnace. Our silicons will average about 2.15 per cent, compared with 0.80 to 0.90 per cent on the two furnaces described.

The ores used at Woodward for the most part are Red Mountain ores similar to those used at Fairfield; however, after going through a 3½ in. crusher, the ore is screened into three sizes instead of two as at Fairfield: The coarse size being plus 1¼ in.; medium, minus 1¼ in., + ⅜ in., and fine, minus ⅜ in.

A close check is kept on the results of the screen tests on the three sizes of ores, and corrective measures are taken as required. These measures consist of adjusting the crusher opening or a change in screen cloth to a different size opening.

The dust production for 1949 at Woodward was 67 lb per gross ton of pig; this dust being made on comparatively high unit blast volumes. Low dust production on high blast volume is easier to obtain with hard southern red ores than with the soft Mesabi ores. We blow 208, 217 and 217 cfm. Part of this high blast volume can be attributed to our air conditioning, by which moisture is held to 2.85 grains per cu ft the year round. As an indication of the effect of humidity on blast furnaces, we had one dehumidifier out of service for a period of 10 days during June 1947. During this period, the furnace tonnage decreased 60 tons per day, and the coke practice increased 235 lb per ton.

Mr. Hogberg makes the statement that the furnace operator must contend with more than 50 variables in the production of pig iron. One of these is blast heat. We have eliminated this as a variable by setting 1400 F on one furnace, 1425 F on the second, and 1200 F on the third; because this is all we have. These heats are rarely changed, and then only when necesary to make 0.50 to 0.75 silicon. The advantage of this operation is that it removed the human element that may be wrong as many times as right in making heat changes. It also tends to keep the zone of fusion in the same place at all times.

As is usual in southern operations, furnaces are checked at 20 minute intervals by slacking the blowing engines on whistle signal from the furnace, the snort valve being used only when necessary to pull the pressure under 6 psi as in case of a tight furnace. Generally, checking on 20 minute intervals will result in the stock settling four feet. It is necessary in this method of operation to get a good movement at every check. The whole stock column must settle uniformly. No movement, or a one-sided movement will immediately cause the furnace to go on "saw tooth" high pressure due to the packing of the stock column and closing up the voids. This condition then causes a change in the normal gas travel. Bosh slags that were free running become viscous because of the temperature drop. Slag that has just started to form, due to the temperature drop, returns to a gummy pasty mass. During this period, the pressure continues to climb, and the furnace is not getting the wind which further aggravates the situation. If, on the next check, a uniform move can be obtained by pulling the pressure low enough, by means of the snorter, the gas travel in the stock column will be returned to normal over the entire plane of the furnace, and the furnace will return to normal inside of an hour, if these normal conditions are maintained. The above explanation describes the sequence of events in a furnace "going bad."

Mr. Hogberg's deductions as to the reasons southern furnaces require a regular slacking of the blast under normal operations seems logical; however, Woodward furnaces are all larger than 14 ft in hearth diameter, and at times will move by themselves, particularly when being blown in from a bank, or being blown in after a relining. They will also occasionally take spells and move by themselves other than the two cases mentioned above. When this occurs, we immediately take action to stop it by checking at 15 minute intervals, or by slacking the blast pressure considerably lower than normal practice. Our experience has been that a furnace moving itself will go cold, make considerably more dust, as well as making it irregularly, and will not make uniform quality iron.

The reason for the furnace moving by itself after a relining or blow-in from a bank is because the wind blown is much lower than normal at these itmes, which tends toward lower pressures, and the stock column is mostly coke due to the light burden being carried when starting up. The downward movement of the stock column is caused by the reduction of volume in the bosh due to the coke burning up and the stock column moves down freely to fill the space made by the combustion of the coke. The occasional spells of free moving under otherwise normal operations could be caused by some change in the coke, which would tend to make it fast burning, this condition being more prevalent on a shorter coking time. The furnace would then tend to move by itself due to the rapid decrease of volume in the bosh.

In order for us to keep informed as to gas flow, we have installed four thermocouples equally spaced around the circumference of the furnace 12 to 15 ft below the stock line. The end of the couple is flush with the inside of the lining. As long as these couples read approximately the same temperature, the gas flow is uniform. If the temperature starts to drop on one of the couples, steps are taken to bring it back to the same temperature as the other three. This is done by heavy blanks of coke normally 18 to 30 skips, depending on conditions. If this does not bring results, we will charge

another heavy blank of coke and a 100 per cent coarse ore burden for 24 hours. This treatment is usually sufficient. In extreme cases, it may require the coarse ore burden be charged for 72 to 96 hours, and in addition, we will plug 2 or 3 tuyeres opposite the low temperature couple.

As mentioned by Mr. Hogberg we also find that heavy blanks of coke normally do not appreciably increase the silicon content of the iron on a furnace which is working abnormally.

We do not find that conditioned ore has caused excessive erosion on furnace linings. In fact, the reverse is true. One furnace relined in 1932 had 600,000 gross tons on the lining. The lining tonnage has progressively increased since that time to 1,227,000 gross tons in 1945. A second furnace increased from 355,000 gross tons in 1938 to 1,033,000 gross tons in 1948, and our small furnace from 137,000 gross tons in 1937 to 1,007,000 tons in 1948.

All furnaces have 6 to 9 rows of cooling plates above the mantle.

E. A. Hawk: Calculating the fuel requirements for slag by difference, may lead to error, especially when the base point has a low slag volume. For example, in place of the calculation in the paper, as

$$\frac{1852\text{-}1266}{2040\text{-}968} = \frac{586 \text{ lb carbon}}{1072 \text{ lb slag}} = 0.547 \text{ lb carbon per lb slag}$$

a deduction should first be made for a portion of the slag being heated by excess heat on the low slag volume furnace, such as about 0.25 lb per lb Fe. The calculation would then be:

$$\frac{1852\text{-}1266}{2040\text{-}(968\text{-}500)} = \frac{586 \text{ lb carbon}}{1572 \text{ lb slag}} = 0.372 \text{ lb carbon per lb slag}$$

Comparing Edgar Thomson, prepared and normal, the calculation would be:

$$\frac{1498\text{-}1266}{1264\text{-}968} = \frac{232 \text{ lb carbon}}{296 \text{ lb slag}} = 0.783 \text{ lb carbon per lb slag, which, obviously is too high.}$$

Again, correcting for the low slag volume, we have,

$$\frac{1498\text{-}1266}{1264\text{-}(968\text{-}500)} = \frac{232 \text{ lb carbon}}{796 \text{ lb slag}} = 0.291 \text{ lb carbon per lb slag.}$$

However, when comparing Edgar Thomson, normal with Fairfield prepared, the correction for low slag volume is not so necessary as:

$$\frac{1852\text{-}1498}{2040\text{-}1264} = \frac{354 \text{ lb carbon}}{776 \text{ lb slag}} = 0.455 \text{ lb carbon per lb slag.}$$

Correcting for moisture and furnace volume, would lower this to 0.401 lb carbon per lb slag.

As this correction is more by rule of thumb, a more reliable method is desired. Based on 120 blast furnaces, Edgar C. Evans, in paper "Fuel Problems in the Iron and Steel Industry," International Conference on Bi-

TABLE XVI

Data for Edgar C. Evans Equation

	Edgar Thomson		Fairfield
	Normal	Prepared	Prepared
Hearth diameter, ft-in.	27-6	27-6	27-3
Hearth area, sq ft	595	595	583
Tons Fe/sq ft/day	2.23	2.70	2.17
Lb Fe/sq ft/hr	186	225	181
Lb carbon at tuyeres/ton Fe	1,226	1,032	1,514
Lb carbon at tuyeres/sq ft/hr = C_1	114	116	137
Lb slag/ton	1,264	968	2,040
Lb slag/sq ft/hr	118	109	185
Hot blast temp, F	969	916	932
Hot blast × 0.000317 = A	0.307	0.291	0.296
Equivalent heat A × C_1 = C_2	35	34	41
$C_1 + C_2$	149	150	178
Hot blast, per cent total heat calculated	23.5	22.7	23.0*
Hot blast, per cent total heat actual	23.7	22.7	24.7
500 ÷ D	18.2	18.2	18.3
Lb slag per lb Fe	0.632	0.484	1.020

*No correction for moisture.

Edgar C. Evans Factors

Edgar Thomson, Normal	149 = 18.2 + 0.56 × 186 + 0.28 × 118 149 = 155.4
Edgar Thomson, Prepared	150 = 18.2 + 0.56 × 225 + 0.28 × 109 150 = 174.7
Fairfield, Prepared	178 = 18.3 + 0.56 × 181 + 0.28 × 185 178 = 171.6

Revised Factors

Edgar Thomson, Normal	149 = 18.2 + 0.538 × 186 + 0.260 × 118 149 = 148.9
Edgar Thomson, Prepared	150 = 18.2 + 0.527 × 225 + 0.130 × 109 150 = 150.9
Fairfield, Prepared	178 = 18.3 + 0.500 × 181 + 0.375 × 185 178 = 178.2

tuminous Coal, 1928, used 0.56 lb carbon per lb Fe and 0.28 lb carbon per lb slag in calculating fuel requirements at the tuyeres. The complete formula is:

$$C_1+C_2=\frac{500}{D}+0.56\ Fe+0.28\ slag.$$

Where

C_1 = lb carbon gasified at tuyeres per sq ft hearth per hr

C_2 = lb carbon per sq ft hearth per hour as the CO equivalent of sensible heat in the blast, as hot blast temperature F $\times 0.000317 \times C_1$.

Where

$$0.000317=\frac{5.75\ \text{lb air per lb carbon} \times 0.241\ \text{SpHt}}{4375\ \text{Btu}}$$

D = Diameter hearth in feet. $500 \div D$, represents the carbon sq ft hearth per hr for holding.

Fe = lb iron per sq ft hearth per hr

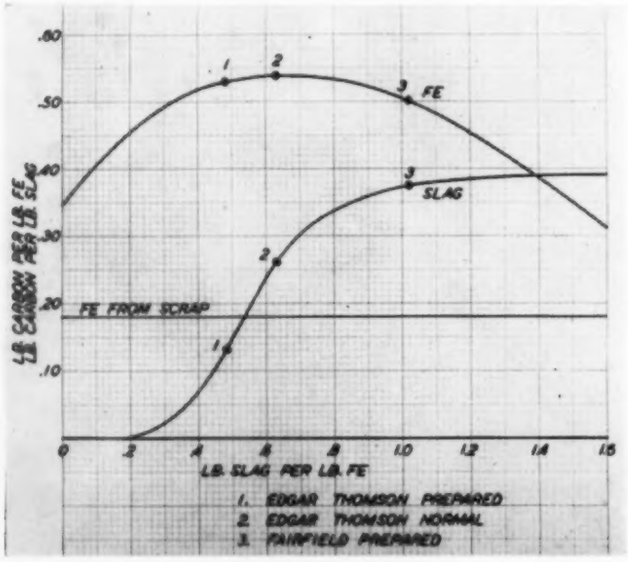
Slag = lb slag per sq ft hearth per hr.

The calculations for this formula are shown on the accompanying data sheet of Table XVI. The variations between the right and left side of the equations are as follows:

	Edgar Thomson		Fairfield
	Normal	Prepared	Prepared
Left side	149.0	150.0	178.0
Right side	155.4	174.7	171.6

It will be noted that the equations do not balance, the right side being greater for Edgar Thomson and lower for Fairfield. Based on the carbon at the tuyeres, sensible heat in the blast, and holding fuel, revised factors were developed for Fe and slag to accommodate the three conditions. Curves were then made for Fe and Slag as shown in Figure 3. Applying the revised factors for Fe and Slag, we have

Figure 3 — Chart gives carbon at tuyeres for Fe and slag.



	Edgar Thomson		Fairfield
	Normal	Prepared	Prepared
Left side	149.0	150.0	178.0
Right side	148.9	150.9	178.2

where the right side of the equation is in balance with the left side.

To establish the trend of the curves, the following is submitted: The three reactions for reduction of iron ore by CO are:

	Btu per lb carbon	Lb carbon per ton 1500 F equilibrium
1. $3\ Fe_2O_3+CO=2\ Fe_3O_4+CO_2$	Plus 3420	80
2. $2\ Fe_3O_4+2\ CO=6\ FeO+2\ CO_2$	Minus 848	160
Total $3\ Fe_2O_3+3\ CO=6\ FeO+3\ CO_2$	Plus 576	240
3. $6\ FeO+6\ CO=6\ Fe+6\ CO_2$	Plus 351	480
Total $3\ Fe_2O_3+9\ CO=6\ Fe+9\ CO_2$	Plus 927	720

In other words the complete reduction is a plus reaction, and the third and last reaction requires twice as much CO as the first two. J. B. Austin,[2] in his paper "Efficiency of the Blast Furnace Process," p 207, Proceedings Association of Iron and Steel Engineers, 1939, states in substance, it is evident that a gas which contains enough CO to reduce FeO under equilibrium conditions, has more than enough CO to reduce an equal amount of Fe_3O_4 and of Fe_2O_3 to Fe_3O_4 as well. Therefore, the CO requirements for FeO to Fe establish the carbon factor for Fe.

In addition to the plus reaction in the reductions of Fe_2O_3 by CO, the heat at the tuyeres, developed by the combustion of carbon to met the CO requirements for reduction, is more than enough to smelt the iron. The surplus heat is either absorbed by slag, reducing slag requirements, or as absorbed by a scrap charge, or by direct reduction.

The downward trend in the Fe curve on the left is due to direct reduction, which absorbs heat and lowers the carbon factor for Fe, the reaction for direct reduction above tuyeres being as follows:

$$\left.\begin{array}{l} FeO+CO=Fe+CO_2\ \text{Plus 351 Btu per lb carbon} \\ CO_2+C=2\ CO\quad \text{Minus 5830 Btu per lb carbon} \end{array}\right\}$$

$$\text{Minus 5479 Btu per lb carbon}$$

In this case one CO at the tuyeres is increased to two CO above tuyeres, which condition reduces the carbon factor for Fe. The downward trend to the right on the FE curve is due to the increase in carbon to CO at the tuyeres to meet the heat requirements for the increase in slag.

At low slag volumes, there is sufficient heat to melt the slag. Therefore, the slag requirements in this area approach zero. As the slag volume increases, the requirements for carbon as CO increases until a balance is reached as shown by the flatness of the slag curve to the right.

The factors for Fe and slag at the tuyeres are shown as follows:

	Edgar Thomson		Fairfield
	Normal	Prepared	Prepared
Fe	0.538	0.527	0.500
Slag	0.260	0.130	0.375

The total carbon for Fe or slag would be calculated as follows:

$$\frac{\dfrac{C_1}{\%\text{ carbon at tuyeres}}+C_2}{C_1+C_2}=C_3;\ C_3\times\text{Fe factor or slag factor}=\text{total carbon factors}$$

For example, for Fairfield prepared:

$$\frac{\dfrac{137}{0.894}+41}{178}=\frac{194}{178}=1.09 \text{ and } 1.09\times0.375=0.409 \text{ lb total carbon per lb slag.}$$

This compares with 0.507 lb carbon per lb slag in Mr. Hogberg's paper.

To simplify the curves, no allowance has been made for scrap. For 5 per cent scrap the Fe factor would be 0.02 lower, and, at 1.0 lb slag per lb Fe, the slag factor would be about 0.02 greater. However, as the amount of slag would be less with scrap, the new factor for slag would be about the same as without scrap.

The curves demonstrate a method of arriving at fuel requirements for slag. With data from a group of furnaces, the curves would be more representative of average practice.

W. D. Harris: This paper is of particular interest to those of us who have had experience only in southern practice but who can now feel qualified to discuss both sides. I especially wish to compliment Mr. Hogberg on his sound theories, along with his compilation of practice data and thermal calculations.

I would like to elaborate on a few of the points brought out in this paper. When one considers the low iron content of our ores, together with the high slag volume and using Mr. Hogberg's calculations of 60 lb of coke per 100 lb of slag, it is seen that our coke practice is in line with northern practice. Knowing our worries from "dusting" furnaces we readily understand why Edgar Thomson cannot blow as hard as Fairfield No. 7. Our coke as well as flue dust rate is raised by the 20 per cent carbon present in our flue dust. I might mention here that the coke rate on No. 7 furnace has been a little lower for the two succeeding months of February and March, or about 2110 lb per ton of iron with approximately the same metallic mix.

Mr. Hogberg's comments on the descent of furnace stock were very interesting. While it may be true that northern furnaces are more sensitive to channeling of gases and irregular movement when blown at an increased rate, they do not have a monopoly on this characteristic, as evidenced by our flue dust rate, and blow-throughs.

We do not feel too badly about our "slacking" as we have long since found out it is the only way to make quality iron on our large basic furnaces. Some few have had the temerity to experiment on not slacking only to find themselves nursing a sick baby all night. We really do not slack every 20 minutes though as Mr. Hogberg states, but rather from 25 up to 40 minutes, depending on the speed of the stock travel on the particular furnace. I can readily understand why it seems like every 20 minutes to a visitor. The lower melting point of our local ore, and when crushed to the small size greatly increases the presure drop through the stock column, as Mr. Hogberg aptly puts it, "And the increased depth over which voids in the ore tend to disappear, due to the increased intimacy of contact and the softening of the ore as the gangue melts, would appear to offer ample reason for the tendency of the southern furnace to hang," and I add, for the pressure to increase.

Although the blast pressure for January was 27.5 psi average, it is all too frequently at levels of 29 to 31 psi. Since the maximum available pressure of our 4-stage blower is only slightly higher than our normal operating pressure, any slight irregularity inside the furnace causing these rises will result in a loss of wind. This is progressive with a rapid loss of wind delivered by the turbo-blower. Coke blanks have been found to be the quickest and best means of relief at Fairfield. Mr. Hogberg mentions the difficulty of utilizing high blast heats while on Mesabi ores. This is also a big problem with us at Fairfield, as high heats invariably cause high pressures and "sticking" furnaces. The use of high blast heats as well as the near elimination of coke blanks has been accomplished at Ensley; more on this subject later.

I agree that small furnaces move more freely than large furnaces. In a great measure this is due to lower pressure, and this from smaller hearth diameters and less height. Our large furnaces will work more smoothly and move rather freely on pressures under 18 psi but this figure has been attained only on foundry iron or on a large per cent of coarse ore, both resulting in a loss of burden ratio. The height of the furnace increases the pressure. In regard to the lines of No. 7 furnace, I believe that the present height above the bosh is too great. A decrease in this height would tend to lower the excessively high zone of fusion, and blast pressure. When you consider that 80 per cent of the ore in our practice is reduced at the top of the bosh, there should be no ill effects of a chemical nature. At times it has been necessary to operate No. 7 furnace on a 12-ft stock level which I know has a detrimental effect on distribution, but which within minutes lowers the pressure by 3 psi under that of a 6-ft stock level.

Discussion of scab formations was very interesting as our practice is conducive to their formation, and when they turn loose it is not only the cold hearth that we dread, but other disastrous results such as slagged blow pipes and blow stocks. As a recent example of the heat required to melt one of these scabs, I can mention No. 6 furnace around March 4, 1950. We had been operating on slack wind and hard coke, and were sure the walls had built up. While banking this furnace and after charging 124 tons of coke the outlook changed and normal burden was resumed. The two casts made after 12 and 18 hours elapsed time were 1.05 and 1.04 silicon, respectively, or slightly over normal, and this with no other operating changes.

Before leaving the subject of southern blast furnace practice, I want to say a few words about that as Ensley. Three 100,000 cfm, 5-stage, high pressure blow-

TABLE XVII

Furnace No.	Hearth diam, ft-in.	Average daily tonnage	Coke, lb per ton	Wind blown at turbo-blower, cfm	Blast heat	Pressure, psi	Total metallics (ore and scrap, natural)
1	22-0	944	2030	86,000	1091 F	27.2	41.26
2	22-6	1068	2033	92,000	1023 F	26.4	40.62

ers have lately been installed, the last two in 1949. Gas cleaning was also installed and a stove rebuilding program is nearly completed. High blast heats from 1100 to 1150 F have been run, as well as high wind rates and resultant higher blast pressures, these frequently ranging from 30 to 37 psi. However, the turbo-blowers have been able to make the wind required, and overcome the resistance in the furnace within an hour or two. The furnaces utilize the available heat, and actually work smoother on the higher pressures. The tonnages have increased greatly and the coke rates have been lowered proportionately. Table XVII gives data on No. 1 and 2 furnaces for the month of January 1950:

As can readily be seen from the table figures, better performance in southern practice can be obtained from the use of high pressure blowers.

W. R. Bond: Mr. Hogberg's paper has been of particular interest to me. My association for the past three years has been with a company operating a furnace on 2,000 lb or better of slag per ton of iron using 100 per cent conditioned ore.

Shown were the difficulties facing the northern operators both economical and operational, and the value of using prepared ore burdens both as to sizing and conditioning; the effect of slag volume on the coke rate; the effect of furnace design, particularly working volume on the efficient operation of the furnace. The latter is most important, especially when using lean ores.

Occupation of the working volume zone by gangue-making material in excess of that which is necessary for good operation and the coke required to melt it causes decrease in production and efficiency with increased cost. As pointed out by Mr. Hogberg, increased efficiency was obtained at Fairfield by installing stack plates and decreasing the lining thickness. At a northern plant where I formerly worked, excellent coke figures were obtained on a furnace overdue for relining, with wall thickness of approximately 4 in. in the mantle, and lower stack zone. After relining with a 36-in. wall many months elapsed before approaching the former coke figure. We attributed it to decreased working volume on the thicker lining.

It was brought out that sized and conditioned ore may cause early lining wear; this has been our experience. No doubt this is due to the open nature of the burden near the wall and the tendency for the gas to ascend in this area. It is our opinion that full advantage of the working volume when using sized and conditioned ore canot be realized unless the proper filling cycle is used. We experienced our best results when layer filling the furnace, i.e., alternating layers of fine and coarse ore. In our practice it amounted to approximately 1 part of fines, material $\frac{3}{8}$ in. down when including sinter, to 1 part of coarse, $\frac{3}{8}$ in. up to 1 in. plus. The retention time of the gas increased as well as the efficiency. As pointed out, application of high top pressure may assist the northern operators to use the high blowing rates of southern practice. The importance of this is evident as it permits maximum benefit from the working volume. Coke and conditioned ore are expensive and we should endeavor to get everything out of them when they are placed in the furnace. It is possible that for a few minutes after each check in southern practice when the ores are compacted, the gases simulate high top pressure conditions before finding the easiest path of ascent.

Mr. Hogberg brought out that bosh build up occurs in both northern and southern practice. In southern practice it is aggravated by the large slag volume, and in both districts it is aided by limey, primary slags or ore and coke fines. We have used reversed filling with good results and rarely experience trouble. I noticed Fairfield operated on a leaner slag than Edgar Thomson, which would naturally tend to help this condition, also help the coke figure. Contrary to opinion, our best results are obtained when operating on a limey slag, with iron sulphur in the 0.020's and 0.030's. In spite of the high slag volume, we have a self moving operation, blow 80-87000 cfm wind, average 1100 F blast heat, and 20-23 psi blast pressure. I believe Mr. Hogberg's explanation of southern checking practice is reasonable. We find it difficult to operate on the edge "so to speak" regarding coke and heat. This is probably because of the slag volume and variable ore.

It appears justifiable to say it apparently takes 60 lb of coke per 100 lb of slag when comparing the two practices. However, operating conditions and practice —materials as to condition, size, and analysis—play an important part and may alter this figure.

I shall briefly give some comparative results and figures from our operation. During May, 1949, we operated on basic iron and with the exception of Mn ore and scrap, this burden was 100 per cent conditioned and originated from limonite ore similar somewhat, I believe, to the brown ores of Alabama. Figures and results are given in Table XVIII.

We feel we have a very beneficial effect from the porous nature of our ore after drying. Perhaps we simulate future northern practice on lean conditioned and sized ore. Mr. Hogberg is to be complimented on his report. It contains much meat.

Dan Wise: This paper is a commendable effort to compare northern and southern blast furnace operation, which in some respects is apparently as different as black and white, yet similar in others. As brought out, southern operators deserve a lot of credit for developing furnace design and practice for utilization of chemically unpromising southern red ores to the extent that production rates compare favorably with northern practice.

The result of the calculations regarding the effect of

TABLE XVIII

Per cent used	Ore	Fe	SiO_2	Al_2O_3	Size	H_2O	Lb material per net ton hot metal
40.0	Dried limonite	51.52	21.32	4.24	2 parts fine — 3/8 in. down 1 part coarse — 3/8 in. up	.....	1585
29.8	PCW washed (plant crushed, undried)	41.49	18.57	4.12	Coarse — 3/8 in. up	4.38	1190
24.5	Sinter (sinter feed 3/8 in. down)	45.74	21.32	5.40	Physically good	.....	980
2.1	Mn	2.13	14.65	2.42	.....	.....	85
							3840
3.5	Scrap (runner)	.....	.....	.....	.....	.....	126 (100 per cent metallic)
.....	Dolomite	.....	.....	.....	.....	.....	625
.....	Limestone	.....	.....	.....	.....	.....	1270
							1895
.....	Coke (averages approximately 9-10 per cent ash, 0.8 per cent sulphur, 1.0 per cent volatile, 2 per cent moisture, 89.0 per cent fixed carbon)						1860

Ore is dried at 1100 F to remove chemically combined moisture — melts at approximately 2280 F.

	SiO_2	Al_2O_3	FeO	CaO	MgO	MnO	Sul	Ratio
Slag analysis, per cent	33.94	14.55	1.02	43.28	5.01	0.83	1.01	1.42

Slag per net ton — 2077

Ore size (dried coarse and PCW)

	per cent	
on 1 in.	28.7	Approximately 43 per cent of ore burden
1/2 in.	48.2	
1/4 in.	15.6	
10 mesh	3.9	
20 mesh	1.2	
60 mesh	1.1	
Through 60 mesh	1.3	

Top gas, per cent CO — 24.2, CO_2 — 13.4, H_2 — 2.6, N_2 — 59.8

Ore size (dried fine screened through 3/8 in.)

	per cent	
on 1/4 in.	43.10	Approximately 26 per cent ore burden
1/8 in.	34.80	
20 mesh	22.50	
40 mesh	1.2	
60 mesh	0.80	
80 mesh	0.90	
100 mesh	0.80	
Through 100 mesh	5.90	

Top temperature — 300-400 F

Tons of hot metal per day 1,090
Air blast rate, cfm containing 5.2 grains moisture per cu ft 81,827
Flue dust rate, lb per ton iron 196

Furnace dimensions
1 — 3.9 per cent smaller than Edgar Thomson in volume
2 — 13.7 per cent smaller than Fairfield in volume

	Edgar Thomson	Fairfield No. 7	Lone Star
Hearth diameter, ft-in.	27-6	27-3	27-0
Bosh diameter, ft-in.	30-6	31-5	30-0
Stockline diameter, ft-in.	21-0	21-0	20-0
Large bell diameter, ft-in.	15-5	15-0	15-0
Total height, ft-in.	105-3	108-8	109-10 1/2
Working height 6 ft below bell and tuyeres, ft-in.	79-6	86-0	79-9
Total volume, cu ft	51,654	55,836	50,730
Working volume, cu ft	44,849	49,092	43,165
Ratio working volume/hearth	75.5	84.2	75.5
Bosh angle, degrees	81.3	82.0	83.1
Inwall batter, in./ft	1.08	1.16	1.03
Number of tuyeres	18	21	18

slag on fuel consumption is somewhat higher than the 33 lb C per 100 lb slag figure developed from various comparisons of northern practice, and which has been accepted by some groups as being the most reliable yet presented. Acceptance by these groups of the new figure presented would brighten the prospects of low gangue foreign ores in this country.

In the discussion of southern practice it was noted that despite the higher gas velocity and moderate top water usage, the top temperatures at Fairfield were relatively low. It is suggested that supplementary to the generous working volume at Fairfield, this was also due to better gas-solid contact in a more permeable stock column. The superior screen analyses of the prepared Fairfield burden would indicate that such a condition did exist.

The discussion of furnace movement and hanging is very interesting. Indeed it does appear that the problem of developing furnace designs and practice to permit regular movement of furnaces producing basic iron from southern red ores is almost insurmountable. However, the gains that might be realized by eliminating conditions leading to regular checking of the furnaces to bring about movement, make this a bright goal to encourage future achievements.

In speaking generally of furnace design, the success of large working volume is important. Not only has this been proven in the south for many years, but the benefits of such a trend have been demonstrated in the north in recent years. While the new, big Northern U. S. Steel Corp. furnaces have been built according to this trend, at Gary a 20-ft 6-in. hearth diameter furnace was built some years ago with a working volume to hearth area ratio of 83.3 which closely approximates the 84.2 of Fairfield's No. 7 furnace. It is worth while to note that this furnace has consistently been a standout furnace at Gary and has ranked very favorably in corporation standings. The performance has been favorable not

only from a statistical standpoint, but also from an operating standpoint.

The profiles of southern corporation furnaces have changed considerably in the past ten or fifteen years, with a marked trend toward very high boshes. It is noted, however, that the large new Fairfield No. 7 furnace, while it does have a high bosh, does not have as high a bosh as some of its smaller predecessors. It would be interesting to hear comments relative to the movement of the furnaces before and after the boshes were raised, and also how the movement of Fairfield's No. 7 furnace compares with other furnaces having higher boshes. While experience has indicated that low, very steep boshes promote smoother furnace movement, this type design does not lend itself to furnaces with large working volumes to hearth area ratios. From it it would appear that furnace design studies in the immediate future would have as a goal the determination of the best compromise between these two and other related factors.

C. G. Hogberg: It is apparent from the interesting discussion presented by Messrs. Byrns and Hawk that we did not make it sufficiently clear in the paper that the 50.7 lb of carbon refers to the requirement of carbon in coke charged in the furnace top per 100 lb of *additional* slag over the northern practice.

We cannot seriously object to the contention that, at a certain low slag volume figure, the carbon required for reduction supplies heat which can be utilized in the melting of slag. However, we are familiar with blast furnace practice with slag volumes below 500 lb per net ton of hot metal, and there was no indication of excess heat available for the melting of additional slag without incurring a pronounced increase in coke rate. It is our opinion that the "low" slag volume of 968 lb per net ton of hot metal for the prepared ore burden at Edgar Thomson works is well above the point below which little or no additional fuel carbon is required to melt slag.

Mr. Byrns mentions that the Woodward slag volume is " . . . 1994 lb per ton of pig, as compared with Fairfield's 2040 lb, and our coke practice on a net ton basis is 2174 lb against their 2170." In order to properly compare Woodward's and Fairfield's practice, it seems necessary that consideration must be given to the fact that blast conditioning and higher ratios of working volume to hearth area at Woodward would result in a corrected coke rate significantly higher than at Fairfield, despite a negative correction for the 1.35 per cent difference in silicon in hot metal. Accordingly, we can find nothing in the Woodward data to alter our original conclusions on fuel carbon requirement for increased slag.

Mr. Hawk's calculations do not recognize that our figure of 89.4 per cent carbon gasified at tuyeres at the Fairfield practice (Table XII) refers to the percentage of carbon as related to the total carbon gasified in the furnace. However, when related to the total carbon in coke charged, which is the basis on which coke/slag calculations are made, this figure drops to 81.7 per cent. Substitution of the latter figure in the formula shown in the closing section of Mr. Hawk's discussion increases his revised factor from 0.409 to approximately 0.447 lb total carbon per lb of slag.

Mr. Hawk has applied an equation developed in 1928, which, in the words* of the original authors, " . . . is, of course, only a first approximation, and is subject to revision whenever better methods of investigation and/or more accurate blast furnace records become available." The Evans-Bailey equation was deduced on the basis of operating results from 120 blast furnaces.

Mr. Byrns has raised a question concerning the possible deleterious effect of the higher magnesia content in slags at Fairfield. We feel that any unfavorable effect of magnesia in Fairfield slag is more than compensated for by the significantly lower ratio of bases to silica; we would hazard the opinion that if Fairfield were required to produce hot metal containing an average of 0.030 per cent sulphur, as at Edgar Thomson, the coke rate would increase at least 100 lb per net ton of hot metal.

In general, we feel that insufficient attention has been given to the fact that with an increase in slag volume, the furnace holding capacity for iron units decreases disproportionately and that physical as well as thermal and chemical factors are involved.

Mr. Harris' remarks on the results obtained at Ensley works with higher blast pressures are timely, and it is hoped that detailed information on this development will be made available.

Mr. Bond's reference to free stock movement in the Daingerfield furnace and his operating data are most interesting. The achievement of an 1860 lb coke rate on a 2077 lb slag volume is outstanding, particularly in view of the 1895 lb flux rate and notwithstanding the desirable physical character of his ores. We do not hesitate to state that Mr. Bond's data raise a serious question on the validity of our 50.7 carbon/slag factor, but it may be well to keep in mind that both the Mesabi ores and the Red Mountain ores referred to in the paper are hematites, in contrast with the limonites used at Daingerfield. Nevertheless, a detailed paper covering heat and material balances for the Daingerfield practice would be enlightening, and we hope it will be forthcoming soon.

Mr. Wise has raised an interesting point concerning the relative desirability of the low, steep bosh in contrast with the higher bosh on furnaces having larger working volumes. The development of the compromise suggested by Mr. Wise will probably depend to a large extent on the rapidity with which fully beneficiated ore burdens are adopted in northern practice, and the degree to which a solution is approached in the problem of utilizing high blast heats. With high blast heats properly and successfully applied to obtain lower coke rates, the need for increased working volume would not be as pronounced. As stated in the paper, the possibility of applying yet steeper bosh angles to achieve successful use of higher blast heats is intriguing and appears to be one of the promising avenues of potential improvement in present day practice.

We appreciate and are encouraged by the courteous remarks made by various contributors to the discussion.

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*"Blast Furnace Data and Their Correlation," Edgar C. Evans and F. J. Bailey, Journal of the (British) Iron and Steel Institute, No. 1 (1928).

PROPERTIES OF AVAILABLE BLAST FURNACE REFRACTORIES

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. . . . the most economical refractory is not necessarily the one with the lowest initial cost . . . .

▲ THERE has been a considerable revolution in thought concerning blast furnace refractories during the last twenty years. Only a few years ago, a suggestion of the use of any refractory which cost more than the then standard material was met with immediate censure by most operators and managements. Now, however, it is generally recognized that better refractories quickly pay for themselves, despite higher initial costs, if only small increases in furnace life are obtained.

This situation forces a broad re-evaluation of the refractory materials which have been commonly used in blast furnace linings, and invites consideration of many materials which formerly were thought to be too expensive. As a result, many new and improved refractories that are well suited for blast furnace linings are now being tried. Other untried refractories are being considered because their properties are known to resist the destructive forces which normally wear out blast furnace linings.

The properties which are desired in blast furnace refractories are fairly well known. This information has been developed through many studies of the causes of failure of blast furnace linings and is well documented in the literature. However, a brief review of this subject is necessary before discussion of specific refractories for various parts of a blast furnace lining.

The chief causes of failure of refractories in blast furnace linings are carbon disintegration, chemical attack by alkalies or slags, lack of volume stability, and abrasion.

Carbon disintegration is the result of precipitation and deposition of carbon from carbon monoxide in the interior of a brick. This reaction takes place rapidly at temperatures between 850 F and 1050 F when catalyzed by metallic iron, iron oxides and some other materials. Of these catalysts, free iron oxides are the only ones likely to be found in refractory materials. If brick containing such catalysts are placed in an atmosphere containing carbon monoxide and are held in the critical temperature range, deposition of carbon around the catalyst is rapid. Any pore space nearby is soon filled with carbon, which still continues to deposit, thus shattering the brick from within and in time reducing it to a powder.

Carbon deposition does not occur if no catalytic material is present. Thus, carbon disintegration can be stopped by elimination of the catalytic material or by converting it to a non-catalytic form. The latter can be done in alumina-silica refractories by heating the refractory to a sufficient degree so that all the iron oxide present becomes chemically combined in iron silicates which do not catalyze the reaction. Carbon disintegration can be inhibited by the use of materials of high mechanical strength, low porosity and low permeability. High mechanical strength resists the disruptive action of carbon deposition, while low porosity and low permeability tend to exclude carbon monoxide from the brick interior. Fortunately, all these properties are developed by firing the brick to the high temperatures needed for chemically combining iron oxides with the other refractory constituents.

Chemical attack of blast furnace refractories can result from two sources. First is attack by alkali vapors in the furnace gases; and second is direct attack by liquid furnace slag. Of these, the former is more pronounced in blast furnaces.

The source of the alkalies is the coke ash. At high temperatures the K_2O and Na_2O are volatilized and permeate throughout the furnace as vapor in the furnace gases.

Attack of alumina-silica refractories by alkali vapors can occur in either of two ways, depending upon the prevailing temperatures. At temperatures above about 2200 F the alkalies will combine with the refractory constituents and melt. Therefore, resultant erosion of the refractory is by straight fluxing. At lower temperatures, the alkalies still combine with the refractory constituents, but instead of melting, they cause a recrystallization, forming the minerals kaliophilite or nephelite, with resultant increases in volume. This causes cracking of the brick, and frequently a progressive peeling away or shelling off of the brick surface.

Attack of the refractories by liquid slags is similar to the action of alkalies at high temperatures. Erosion of the refractory by melting or fluxing may occur wherever liquid furnace slags are in contact with the refractories.

Improved resistance to all these kinds of chemical attack can be obtained by the use of materials which are more refractory and those which are less affected by the fluxing agents, because of their physical properties. In alumina-silica refractories, this means the use of materials of high alumina content for greater refractoriness and materials of low porosity and low permeability for physical resistance. The low porosity and low permeability tend to restrict penetration of the refractory by the fluxing agents.

Lack of volume stability is a characteristic of many porous refractories when heated to high temperatures. The reason for this is that refractory materials which are composed of mixtures of different minerals do not have distinct melting points. At temperatures below the temperature at which they become completely molten, they may contain both liquids and solids in equilibrium. When such conditions exist in a refractory brick, shrinkage is apt to occur as a result of the force that the surface tension of the liquid exerts, or deformation or compression is apt to occur when external loads are applied. The ultimate possible change in volume is obtained when the material is reduced to zero porosity. Thus, the possible amount of volume change is proportional to the initial porosity.

All porous fire clay refractories are subject to this action.

To provide volume stability, refractories which consist of substantially one mineral, such as sillimanite or carbon, may be used; materials made of mixtures of minerals can be given increased resistance by increasing the amount of the more refractory constituent, thus increasing the proportion of solid to liquid; and by the use of dense, low porosity materials generally.

Abrasion is one of the lesser causes of trouble in blast furnace linings. It usually results from falling stock, although occasionally abrasive action of dust in a gas stream that impinges on refractories may cause some trouble. In either event, excessive abrasive wear can be corrected by the use of refractories having sufficiently high mechanical strength.

Various combinations of these major causes of refractory failure are encountered in the different parts of a blast furnace lining. In the top of the furnace, conditions likely to cause carbon disintegration, abrasive action and chemical attack by shelling from nephelite formation are prevalent. In the inwall section, chemical attack by alkalies, both in fluxing and by peeling as a result of nephelite formation, are more severe. Also conditions for carbon disintegration exist and some abrasive action may occur. The bosh section is subject to chemical attack by fluxing from both alkalies and liquid slag, while in the hearth the conditions causing shrinkage and deformation of refractories are predominant. Some chemical attack of refractories is also found in the hearth.

The refractory to be used for each section of the furnace should be selected on the basis of its resistance to the various conditions encountered in individual furnaces. Fortunately, in almost all cases, the refractory properties desired to combat the predominant destructive influence in any one section, also act to retard the action of the other wearing conditions. However, with the wide variation in demands upon the refractories found in the various parts of a blast furnace lining, and in different furnaces, it does not seem logical to search for one material as the best and universal blast furnace refractory.

In recent years, most furnaces have been lined in this way, one fireclay brick being used from hearth to top. Some years ago, most fireclay blast furnace brick were supplied in three qualities which were called hearth and bosh, inwall and top. The hearth and bosh brick were the hardest burned and most dense. The inwall brick were also hard burned, but frequently were not as dense as hearth and bosh brick. The top brick were usually very hard and dense to resist abrasion, but were slightly less refractory because of the lower temperatures prevalent in the top of the furnace.

Difficulties chiefly from carbon disintegration brought about an extension of use of the more resistant hearth and bosh brick throughout the furnace lining. Gradually the different classifications of blast furnace brick were dropped until now most manufacturers supply one regular quality blast furnace brick, for which the older hearth and bosh brick was the model.

Such brick have lined the furnaces that set virtually all the existing records for campaign length, tonnage produced, maximum production rate, etc. They are the standard lining material for most present-day blast furnaces and will probably continue in this position for many years. There are many blast furnaces in which the demands that operating conditions make on the lining refractories, are amply met by the current regular blast furnace brick.

Most regular quality blast furnace brick are made from Kentucky fireclays, and some are produced from Pennsylvania clays. These are carefully processed and grain sized to achieve high brick density. Brick are produced by both stiff mud and dry press processes with deairing techniques. For some time the stiff mud process was thought to be best, but recently improvements in the dry pressing procedures make the dry press bricks equal or better than stiff mud bricks in all respects. Consequently, there is a trend toward the use of dry press material because of their uniformity and excellent workmanship. Blast furnace quality brick are carefully fired to high temperatures to bring out the desired physical properties.

Compared with regular high heat duty fireclay brick, blast furnace brick are virtually a specialty product,

TABLE I

Typical Data on Regular Quality Fireclay Blast Furnace Brick

Chemical analysis:	
Compound	**Per cent**
SiO	51.0
Al_2O_3	40.0
Fe_2O_3	2.5
TiO_2	2.3
CaO	0.25
P.C.E.	**Cone 32-33 (3092 F-3173 F)**
Porosity:	**Per cent**
Open pores	**20**
Closed pores	**1**
Bulk density	**1.26 oz/per cu in.**
Cold crushing strength	**2500 psi**
Modulus of rupture	**1100 psi**
Hot load test (25 psi at 2642 F)	**6 per cent deformation**

despite the fact that the two are marketed at the same price. Entire brick producing plants are devoted exclusively to the manufacture of such blast furnace refractories.

Typical data showing the chemical and physical properties of such brick are shown on Table I. It must be remembered that these data are not in any way to be considered specifications, but are merely typical data. Data on individual brick or shipments might show considerable variation from these figures.

In some blast furnaces and particularly in some sections of such furnaces, regular quality fireclay blast furnace refractories have not been entirely satisfactory. In stacks of some furnaces, they have not been sufficiently resistant to carbon disintegration, while in others they have been subject to severe alkali attack in the section immediately above the mantle. Also in the hearths of some furnaces the bricks have been reduced to zero porosity by shrinkage and deformation under load, thus permitting metal penetration into the joints of the bottom, and in some cases, erosion of the bottom by floating out of the shrunken brick.

To combat these effects, and particularly to eliminate carbon disintegration and inhibit alkali attack, a special blast furnace refractory has been developed. This brick is made from the same materials and by the same processes as regular blast furnace brick, but it is fired to higher temperatures, usually a minimum of Cone 18, to obtain the desired resistance. This material is generally known as high fired blast furnace brick.

These brick show no signs of carbon disintegration in severe laboratory tests which have drastic effects on regular blast furnace brick. No quantitative test for resistance to carbon disintegration has been standardized, so there is no finite way of reporting these data. However, from the work which has been done, it is virtually assured that high fired blast furnace brick are completely resistant to carbon disintegration.

The firing treatment which makes the brick resistant to carbon disintegration also tends to make them more dense, stronger, of lower porosity and permeability, and greater in resistance to deformation under load at high temperature. These properties make them more resistant to chemical attack by either slags or alkalies, and tend to make them more volume stable. This gives such brick advantages for use in the inwalls, bosh sections, and hearths of furnaces in which difficulties are encountered. Such brick are being rapidly introduced into plants where difficulties with regular blast furnace brick have been experienced. In several plants where complete furnace campaigns have been run on complete or partial linings of high fired fireclay blast furnace brick, the results have been considered extremely encouraging, much more than justifying the extra cost of the high fired brick.

Typical data on high fired fireclay blast furnace brick are shown in Table II. Again it must be remembered that these are but typical data and that individual brick or shipments might show considerable variance with the figures shown:

TABLE II

Typical Data on High Fired Fireclay Blast Furnace Brick

Chemical analysis	**Same as regular quality (See Table I)**
P.C.E.	**Cone 32-33 (3092 F-3173 F)**
Porosity:	**Per cent**
Open pores	**15**
Closed pores	**4**
Bulk density	**1.28 oz/per cu in.**
Cold crushing strength	**8000 psi**
Modulus of rupture	**2200 psi**
Hot load test (25 psi at 2642 F)	**0.5 per cent deformation**

Still another fireclay refractory is being tested in blast furnace linings in some places. This material, high-fired super duty fireclay brick, is slightly more refractory than high-heat duty fireclays, having a P.C.E. of over Cone 33 (3170 F). Such brick are resistant to carbon disintegration, also have high density, high strength, good resistance to deformation under load, and low porosity and permeability. These properties are developed in this more refractory brick by very high temperature firing. As a result, the brick are sold at a considerable premium in price over regular fireclay blast furnace brick and are more expensive than the high-fired fireclay blast furnace brick.

To date, only a few test panels and one or two complete linings of this material have been examined after service. Although the results of these tests have been considered encouraging in some quarters, the data are insufficient at present to define the relative worth of this material as compared with regular quality blast furnace brick and high fired fireclay blast furnace brick.

In the use of all the fireclay refractories in recent years, most difficulties have been experienced in the hearth sections where high temperatures and heavy loading conditions are normal, causing severe shrinkage and compression of the fireclay brick. This condition is so severe in some furnaces that all the fireclay refractories can be reduced to zero porosity with a volume shrinkage that is proportional to their original porosity. Thus, it does not appear that any fireclay refractory will ever be sufficiently volume stable to be the perfect hearth refractory.

Difficulties of this nature were observed to a pronounced degree during the early war years when a series of hearth breakouts, particularly in and around the iron notch section, terminated many furnace campaigns prematurely. It was because of these difficulties that so many blast furnace operators climbed on the bandwagon for carbon as a hearth refractory.

From 1944 to 1949 there were about 80 furnaces lined with carbon refractories in their hearths. In view of the high initial cost of carbon as compared with fireclay

refractories, this represented a virtual revolution in blast furnace lining practice.

Carbon has many advantages as a blast furnace hearth refractory. It is in chemical equilibrium with blast furnace slags and metal. Some carbon products are almost entirely volume stable and at the worst they exhibit less than 1 per cent shrinkage. Although carbon blocks may be quite porous they are reasonably impermeable to metal penetration because the carbon is not wetted by the metal. However, experience has shown that carbon refractories are liable to attack from several different quarters, so that at present carbon cannot be regarded as the "perfect" hearth refractory. This has been shown by several recent breakouts of furnaces with carbon hearths.

Some of the difficulties which may be encountered in the use of carbon in a blast furnace hearth are oxidation of the carbon, particularly in the iron notch area; penetration of the joints between carbon blocks by metal inasmuch as carbon paste materials used in joints have appeared to become almost granular after prolonged service; shearing or breaking off of pieces of carbon blocks if metal penetration of the joints has occurred because of the relatively low mechanical strength of the carbon refractories and their high buoyancy in a metal bath; and failure of the fireclay refractories used for backing up the carbon as a result of the high temperatures and heavy loads to which they are subjected. The thermal conductivity of the carbon is very high as compared with other refractories, so that the temperatures to which the back-up brick are subjected are almost as high as they would be if they were directly exposed.

Considerable experimental work both to find proper constructions and to determine correct operating practices must be done before the use of carbon will again be widespread. Adequate cooling techniques, satisfactory joining both as to design and joint material, necessary lining thicknesses, proper water cooling, precautions for preventing oxidation, etc., all must be worked out experimentally. When these things are done, carbon must compete with other hearth refractories on a cost basis.

Meanwhile, another approach to improved blast furnace refractories lies in the field of high alumina materials.

High alumina refractories which would be suitable for blast furnace linings are sillimanite brick and alumina-silica refractories to which additions of bauxite, diaspore, or other highly aluminous materials have been made bringing the Al_2O_3 content of the refractory to a high level. Such materials are highly refractory, have a marked volume stability, and are very resistant to chemical attack. They are dense, strong, and with proper firing are unaffected by carbon disintegration.

These properties make these materials particularly well suited for use in blast furnace bottoms in the hearth wall. They would also be well suited for the lower inwall and bosh sections or wherever alkali attack is a serious problem.

Sillimanite refractories show possibilities as hearth refractories because of their inherent largely crystalline nature. Such brick are made up of a rigid skeleton of interlocking mullite crystals. At blast furnace hearth operating temperatures they would contain only small amounts of liquid, thus they should exhibit little if any shrinkage or subsidence under the prevailing loads. It seems likely that while some metal penetration of the brick might occur, the sillimanite would stay in situ as a highly refractory, slowly eroding layer.

Some experience with sillimanite as hearth refractory is being gathered. From 1938 to 1946, over 20 furnaces in several different plants had sillimanite ramming mix pads installed in their hearths. In all but three of these cases, a 3 to 9-in. thick pad of sillimanite was rammed on top of the hearth blocks. This type of installation is pictured in Figure 1. In this position the sillimanite pad bore the brunt of the severe fluxing conditions of the high alkali content slags which are present during the blowing-in period. In no case did any early hearth trouble occur. It would be difficult to pick at random a like number of furnaces lined during the same period and find that all had had no early hearth breakouts. Table III shows a list of some of these furnaces with the date of installation and the tonnage on the campaign or tonnage to a recent date. While it cannot be proved at present that the sillimanite pad alone was responsible for this fine record, it seems most likely that this is the case. Inasmuch as the cost of a sillimanite pad is less than $5,000 for an average size furnace, installations of this sort appear to be relatively cheap insurance against early hearth trouble.

The three other installations of sillimanite pads in blast furnace hearths incorporate a pad of 6 to 9 in. depth buried under either 24 or 27 in. of fireclay hearth blocks. All three of these furnaces are still operating and have given creditable service already, as may be seen in Table III. Figure 2 is a diagram of such installations. These furnaces showed evidence of "high" bot-

Figure 1 — Diagram of sillimanite ramming mix pad on top of hearth blocks in a blast furnace bottom.

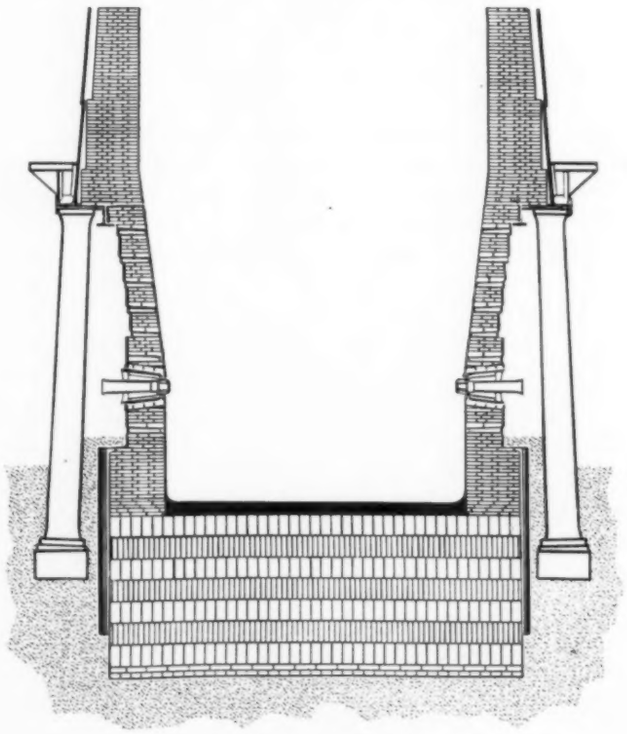


TABLE III

Records of Blast Furnaces with Sillimanite Ramming Mix Pads in Their Hearths

(Pads on Top of Hearth Blocks)

Plant	Furnace	Year Installed	Record	Net tons
A	2	1938	Campaign completed in 1946	2,527,237
B	5	1942	Furnace still on with over	1,700,000
D	2	1943	Furnace still on with over	1,850,000
B	3	1943	Furnace still on with over	1,850,000
D	1	1943	Furnace still on with over	2,500,000
D	3	1944	Furnace still on with over	1,900,000
B	1	1945	Furnace still on with over	1,450,000
F	1	1945	Furnace still on with over	850,000
B	6	1946	Furnace still on with over	800,000
F	4	1946	Furnace still on with over	850,000
D	7	1946	Furnace still on with over	950,000
F	3	1947	Furnace still on with over	750,000
F	6	1947	Furnace still on with over	550,000

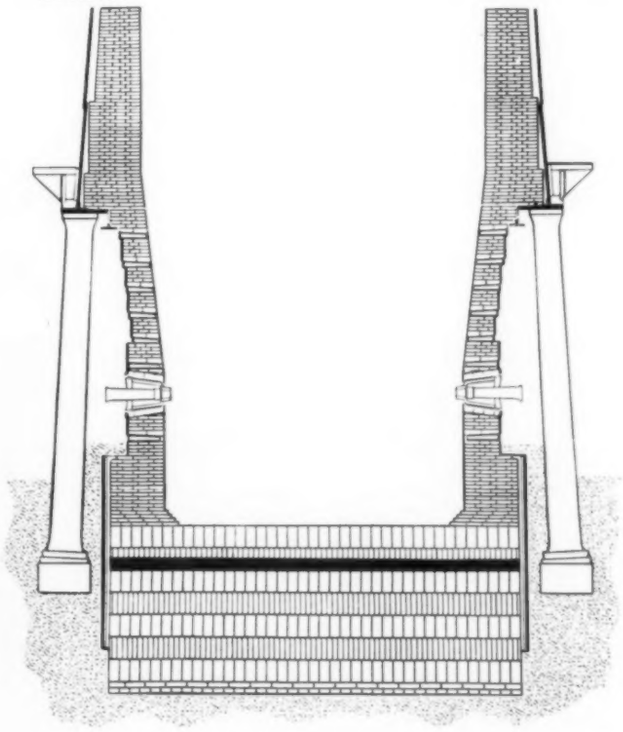
Pads in the Hearth Beneath 24-27 in. of Hearth Blocks

Plant	Furnace	Year Installed	Record	Net tons
C	2	1943	Furnace still on with over	1,850,000
E	2	1943	Furnace still on with over	1,650,000
E	1	1944	Furnace still on with over	1,400,000

toms for long periods after blowing in. However, until one has completed its campaign, no positive proof can be obtained as to the efficacy of the sillimanite pad in this location.

Other use of sillimanite in blast furnaces which has been proved advantageous is the use of sillimanite mortar for laying up hearth and bosh sections. In this application, the sillimanite exhibits its non-shrinking character, tending to inhibit metal penetration into joints in the hearth and forming relatively gas-tight joints in the bosh. Several operators, after using sillimanite mortar in the bosh section for the first time, have commented on the absence of gas in the cast house during blowing-in and the unusually tight bricklaying job which was achieved.

Figure 2 — Diagram of sillimanite ramming mix pad buried under 27 in. of fireclay blocks in a blast furnace bottom.



Other high alumina brick have not been used in as many trials as sillimanite in blast furnace linings. However, the technical considerations indicate that such high alumina brick possess many advantages as blast furnace refractories. Some test installations of high alumina refractories are now in progress, and the increasing general interest in this subject is virtual assurance that further trials will soon be made.

Most high alumina refractories at present are less expensive than sillimanite. However, the present 60 and 70 per cent Al_2O_3 brick are not entirely satisfactory for blast furnace use. Greater volume stability, greater density, lower porosity and possibly even higher Al_2O_3 contents would be needed for best results. Improving these items would increase manufacturing costs so that the ultimate cost of such a brick cannot be set at this time.

The greater availability of alumina as compared with sillimanite seems to indicate that it will supplant sillimanite in blast furnace linings in the future. Further, the great volume stability and extreme resistance to chemical attack by alkalies and slags of high density, high Al_2O_3 content refractories suggests that such brick will yield the best service in eliminating shrinkage of hearth refractories and in maintaining the furnace lines in the stack section.

In many ways the field of high alumina refractories seems to offer blast furnace operators more possibilities for improvement of lining life and furnace production than any other presently known refractories.

Developments in the Design OF Coal and Ore Bridges

By B. A. ROSE
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. . . . advances in electrical, mechanical and welding design are contributing to more dependable and faster operating ore bridges . . . .

▲ MEETING of performance commitments in the design and construction of a coal or ore bridge is of primary importance. However, continued trouble-free operation of the bridge is of vital importance in many cases because of the effect of the bridge's availability on the successful operation of the entire plant. Furthermore the use wherever possible of simple details that are readily dismantled for repair will generally give the lowest maintenance cost. The designer of such equipment should therefore pay particular attention to this phase of the work in his design of the bridge.

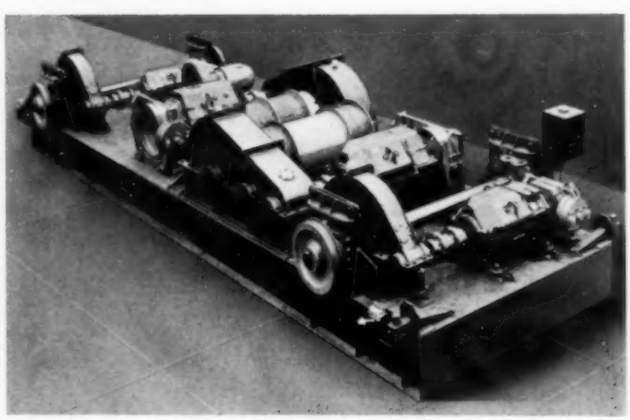
The simple two motor hoist with no extra clutches, brakes or counterweights is generally considered today to be the accepted standard for handling the bucket of the bridge. Such a hoist should utilize totally enclosed, splash lubricated gearing with the bearings of all the shafts carried in the gear cases. The drums for the two motions should be kept separate from each other to facilitate repair or replacement. Full depth gear teeth with pressure angles of at least 20 should be used because of their greater strength and greater wear life. Figure 1 shows a photograph of a trolley equipped with such a hoist arrangement. The supports for the drum shafts, the reducers and the motors are made an integral part of the trolley frame and special attention is given their design to ensure that accurate bearing alignment is maintained.

In many applications there is a need to turn the bucket to facilitate loading or unloading operations. Mounting of the complete hoist on a turntable so that it can be rotated as desired gives the best overall arrangement so far as maintenance of equipment is concerned. The generally accepted arrangement of the two motor hoist is too bulky to be mounted in such a manner without the use of an excessively wide and heavy trolley.

Figure 2 shows a design of two motor hoist which is arranged to be mounted on a turntable. It is a very compact arrangement but the compactness has been obtained with practically no sacrifice in accessibility of parts for inspection or repair. The assembly is mounted on a welded lower member which is in turn carried on rollers supported in the trolley frame. The rotate motion is obtained by a motor driving through a reducer to a final bevel gear reduction, with the gear mounted on the periphery of the turntable structure. Power for the hoist motors is fed through cable loops to avoid the complication necessary with the use of collectors. One hundred eighty degrees of motion can readily be obtained giving the operator entire freedom in placing the bucket as he wishes.

The drums are readily accessible for reeving through the sides of the motor supports. The gear cases are split horizontally at each gear and pinion shaft centerline so that any part of either gear train can be readily replaced. The entire motor, motor support and upper gear case for either hoist can be lifted off to completely expose its drum shaft if replacement of gear or shaft is

Figure 1 — The two-motor hoist trolley is the accepted standard today.



necessary. All gear tooth meshing points are available for inspection through oil tight cover plates. The entire assembly of gears and bearings are lubricated by a bath of oil carried in the gear case.

Accepted practice today for trolley suspensions utilizes nests of coil springs above each axle bearing. Such a spring suspension requires use of guide shoes which need lubrication and adjustment for wear. Furthermore occasional spring failures are encountered. A study of the problem will show that the amount of flexibility required in the suspension has been materially reduced by such improvements as welded track joints as well as improved track supports. Present day track practice justifies simplification of the suspension. The suspension requires some flexibility but the amount should be that required to effectively isolate the trolley from track and wheel surface roughness only. Such defects produce high frequency low amplitude disturbances which are readily isolated by mountains of resilient material such as rubber. Such a mounting, if properly designed, would meet all requirements of the application and would eliminate the adjustment of guide shoes as well as the lubrication now required periodically.

Figure 3 shows a trolley suspension which utilizes four circular inserts at each pillow block to carry the load of the trolley as well as maintain the axle in proper alignment with the trolley frame. The "free" height of the fabreeka pads is 2 in. and with the compression loading of 2000 psi, the static deflection will be approximately ¼ in. The material is a well known shock absorbing material which has proved itself to be entirely satisfactory under much more severe loading conditions. The suspension is simple in construction and requires no attention. A set of inserts is being made for installation in place of the conventional spring assembly on a bridge in operation. A comparison of the results will be made with that of the conventional suspension, and if they are satisfactory, as expected, the new suspension will be adopted.

The cradle type trolley drive was developed as a solution to the gear tooth alignment problem introduced with the adoption of the spring suspension for the trolley. Today it is recognized by operating men as about the best available drive for trolley motions. A critical analysis of it will show, however, that it is complicated and heavy, and is only partially satisfactory in maintaining tooth alignment. Fundamentally such a drive is good and as it is manufactured for street railway practice using special motors with rugged shafts, closely mounted overhung pinions and frame mounted cradle bearings it gives very good results. Compromises such as the use of standard mill motors, pinions carried on two bearings and completely oil tight gear cases have introduced so much weight and flexibility into the drive that it is not the best available today. It is impossible to build a practicable cradle structure that can be suspended on the trolley axle and provide an entirely satisfactory support for the outboard pinion bearing. The flexing of the cradle, with the torque reversals encountered throw the gear teeth out of alignment and work a hardship on the oil seals at the shafts in the cradle mounted oil tight gear case. Standard mill motors, separately supported pinions and oil tight gear

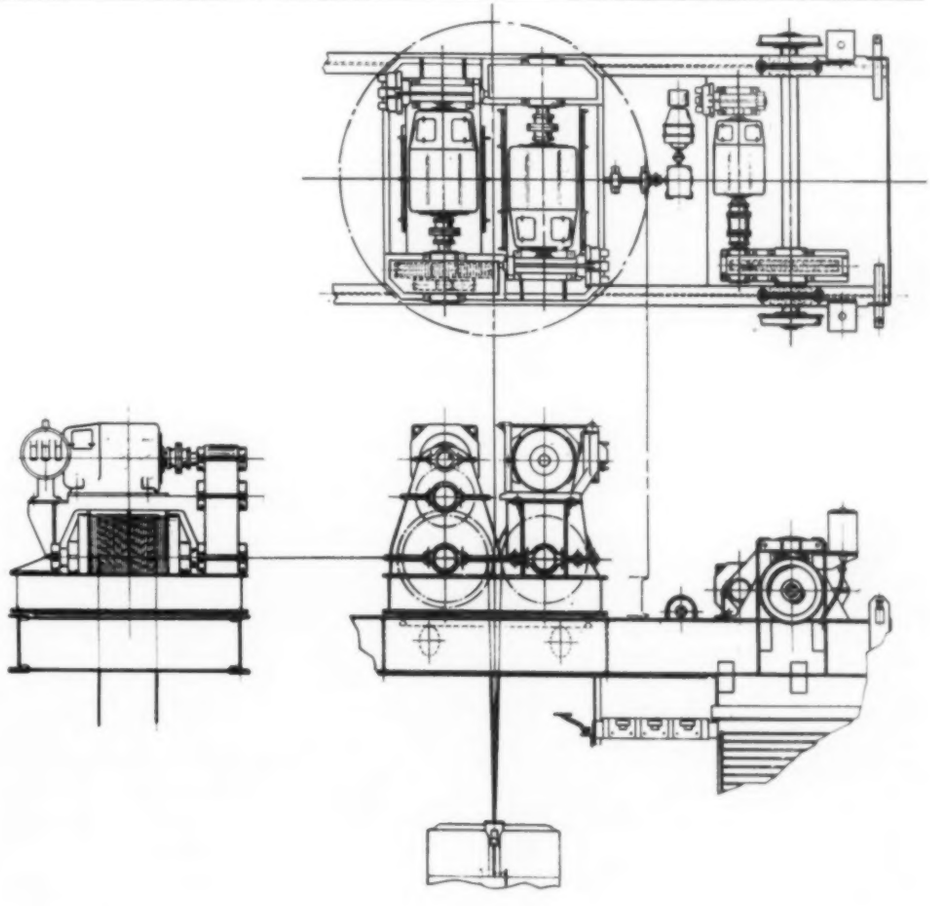


Figure 2—The hoist is designed to be mounted on a turntable.

cases are essential to good performance and should be retained. A type of drive is needed that incorporates these parts into a simple rugged arrangement that inherently maintains good tooth alignment and satisfactory oil seal clearances.

Figure 3 shows a trolley drive which is comprised of an oil tight gear case, carried on the trolley axle by antifriction bearings and hinged to the trolley frame at a point adjacent to the motor pinion shaft. The pinion is carried on antifriction bearings mounted in the case itself. Although the drive is shown with the new suspension, it is in use with the conventional spring suspension as shown in Figure 1. The axle hung gear case ensures accurate gear tooth alignment even though complete torque reversals are imposed on it. Mounting of the oil seals immediately adjacent to the bearings, with seals and bearings supported by the same member, ensures minimum shaft movement in the seals and promotes good seal life. Lubrication of the gears and bearings is provided by the bath of oil carried in the gear case.

The use, wherever possible, of totally enclosed gear units, grease packed antifriction bearings and elimination of guide shoes at the trolley suspensions makes it necessary to inspect the trolley lubrication no more often than once a month.

There is a trend today toward the use of buffers at the ends of the trolley runway which are capable of stopping the trolley from full speed without undue discomfort to the operator. The energy involved is so great, however, and the consequences, in case of a failure of the buffer, are so serious that it appears advisable to study this problem further. The hydraulic buffer is the only device available today that can handle such great amounts of energy and give a reasonably smooth stop. Furthermore, no one will use it except as insurance in case the "slow down" and "final stop" limit switches ahead of it fail to function. It can be criticized as being a complicated device which requires elaborate inspection to ensure its operable condition. The risk involved in a positive test of its condition such as running a trolley at full speed into it is not justified. In view of these facts it appears that a more satisfactory solution to the problem is the use of a simple rugged friction or spring type of buffer as a backup for the limit switches. Extremely large capacity of the buffer should not be obtained at a sacrifice in its certainty of operation. Faults that may exist today in the limit switches used ahead of the buffer can be eliminated, and if given good maintenance they can be relied upon to function properly. Furthermore failure of them will be detected in normal operation while the operator is in proper control of the trolley. Under these circumstances the buffer is needed only as insurance against coincident failure of the operator and the switches. The chances that a trolley will be allowed to strike the buffers at full speed are then so remote that no elaborate safety device is justified.

The worm drive through a final spur gear reduction

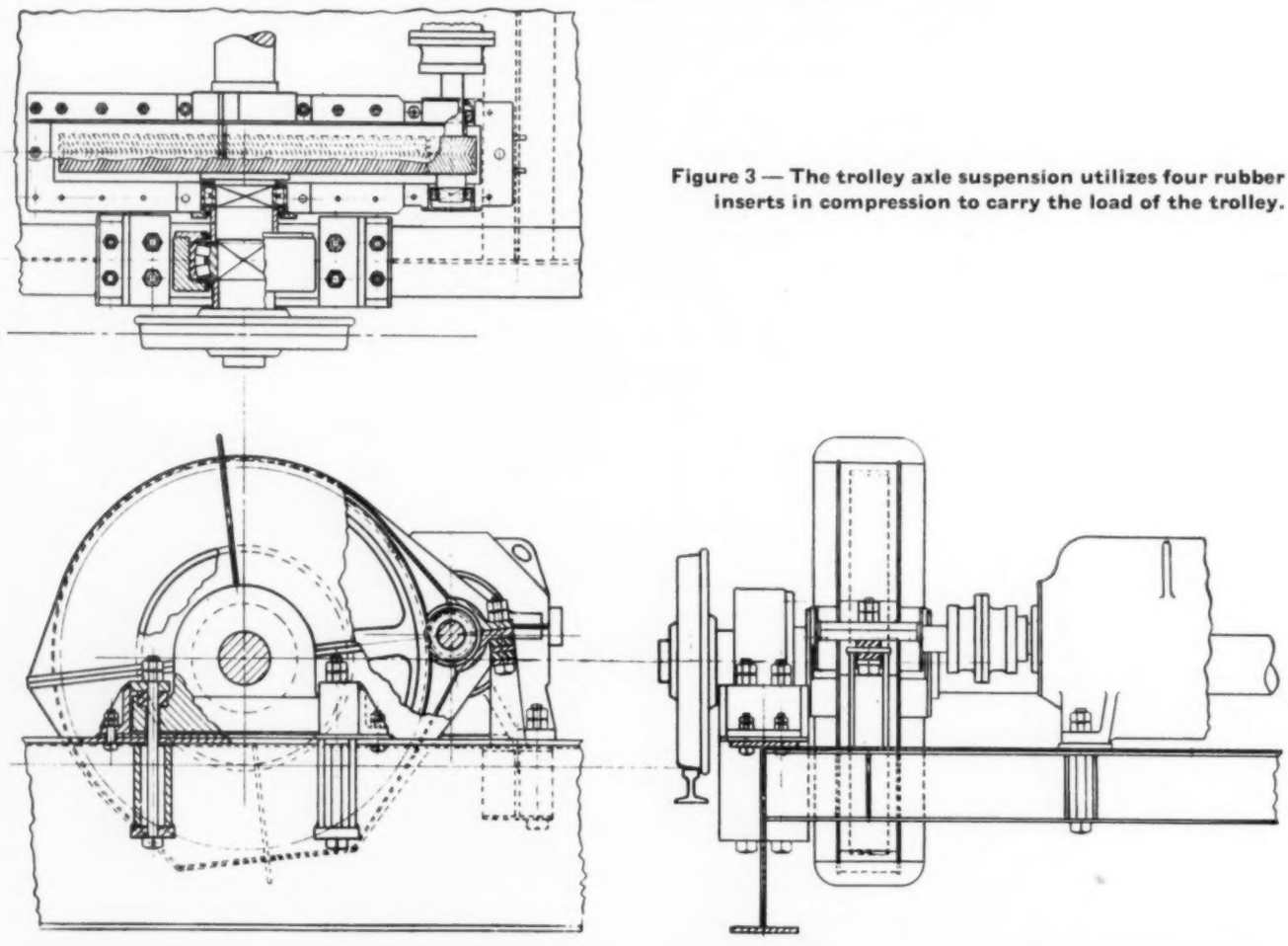


Figure 3 — The trolley axle suspension utilizes four rubber inserts in compression to carry the load of the trolley.

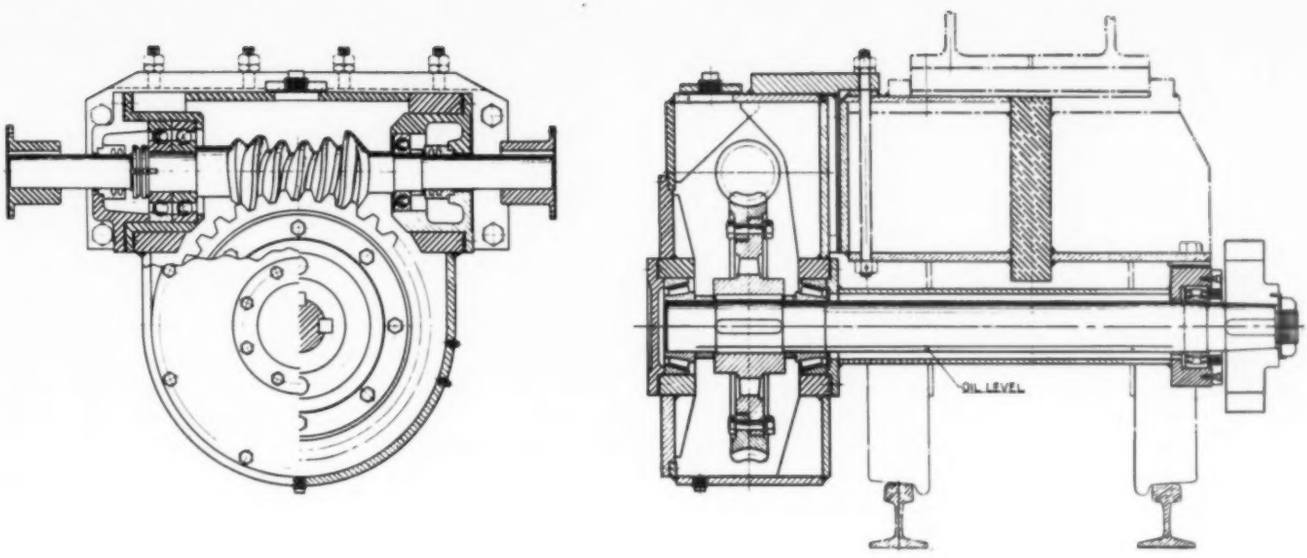


Figure 4 — The bridge truck shown has a worm drive.

to the wheels has become the standard truck drive today. Such a drive provides a good accessibility of its parts for repair or replacement. The worm ratio used is non-locking allowing operation, in an emergency with power to only one motor on a bridge leg. Figure 4 shows a truck drive of this type presently being installed on a bridge. The worm reducer and the bearing adjacent to the spur pinion are combined in one housing to facilitate replacement of the drive in case of trouble. The reducer assembly can be replaced without the removal of a section of track, by pulling the pinion off the tapered fit on the shaft and loosening of bolts between the assembly and the truck frame. A high level of lubricant maintained in the gear case ensures lubrication of the bearing adjacent to the pinion.

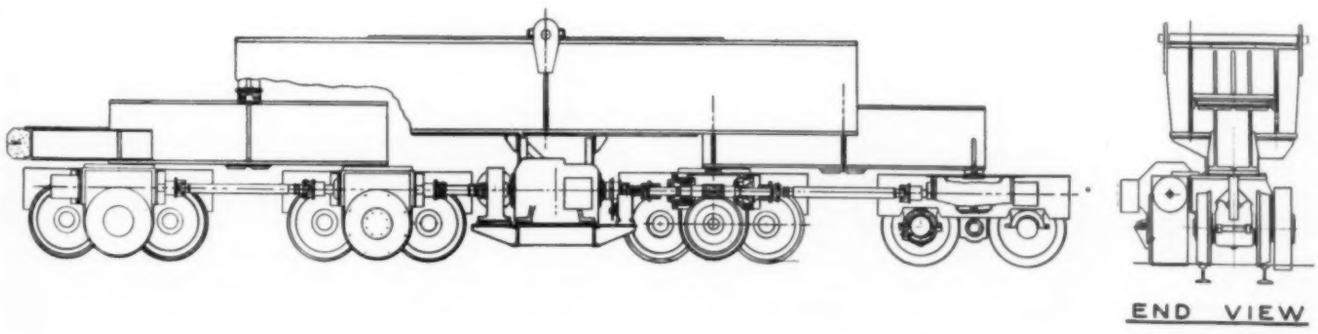
Figure 5 shows the arrangement of the complete truck. Jacking points are furnished beneath the individual trucks as well as beneath the main members so that a single axle or a complete truck can be removed if desired. A single motor is used for power on each corner of the bridge. The drive to the worm reducers is through flexible couplings which accommodate angular and offset misalignment as well as any variation which might occur in the distance between the reducers.

Recent developments in the design of the bridge structure have pointed toward the simplification of it, and the elimination of inaccessible corners and pockets which cannot be adequately protected against rust. Use of wide flange sections instead of the previously used built-up sections has given a bridge structure that is much more easily cleaned and painted.

Further simplification of parts of the structure can be made by use of welding instead of riveting and some applications of welding have already been made to the shear and pier legs of bridges. Welding allows simplification of the connections because of the smaller area required for the same strength in a welded joint. Gusset plates, connection angles and other connection material can thereby be eliminated making a cleaner structure that is more easily protected from corrosion.

In view of the advantages to be obtained from the use of welding, it is well to study further the possible complete replacement of riveted construction with welding on an ore or coal bridge. The principal problem involves the comparison of the abilities of the two types of connections to withstand the loading encountered throughout years of service. Parts of a bridge structure, such as the legs, encounter mostly compressive stresses that pulsate very little. On the other hand, parts of the span structure encounter fairly high tensile stresses that change in magnitude as the trolley changes its position on the runway. This change in stress is fairly

Figure 5 — View is given of a complete worm gear-driven truck.



large on cantilevered bridges where the trolley passes from between the legs out onto the cantilevered runway.

In comparing joint strengths it can be said that a welded joint can always be made superior to a riveted joint because it can be made full sectioned and shaped so that stress concentrations are held to a low value. The riveted joint, in comparison, has its rivet holes which are discontinuities at which heavy loads are transferred from one piece of the joint to the other. The stress concentrations at these points are quite high. To further complicate the picture, the generally accepted welded joint composed of one member lapped over the other and welded to it along its edges is probably inferior to the riveted joint, because of its great concentration of stress at the outer ends of the fillet welds. Furthermore the riveted joint has a certain amount of flexibility which allows it to escape the greater part of the secondary stresses that the welded joint has to withstand because of its rigidity.

The above comparison only shows the complexity of the problem of comparing riveted and welded construction and does not point out a solution. The designer should make adequate allowance for the presence of the pulsating loads in the structure in his design of the welded joints. Furthermore it would appear that welded construction is entirely satisfactory for the legs of a bridge even with the use of the common lap welded joint. Welding on the span, however, especially on the tension members that encounter pulsating stresses, should be carefully studied to ensure that endurance limits in the materials are not exceeded by the peak stresses at the joints.

There has been little interest shown to date in the use of variable-voltage drives for the hoist and trolley motions of man trolley bridges. Such a type of drive has, however, proved itself to be very satisfactory for the same type of motions on heavy shovel and dragline equipment. Application of the variable voltage equipment to man trolley bridges necessitates the use of quite a number of control conductors which is a disadvantage that must be overcome. There are several definite advantages, however, that such equipment has over other schemes that make its adoption well worth considering. Approximately two-thirds of the control weight normally carried on the trolley with the rheostatic scheme can be removed. This amounts to as much as 7000 to 9000 lb. On long runways the use of the higher voltage on the bridge collectors cuts power loss as well as the first cost of the heavy copper conductors that are necessary with the rheostatic scheme. In new installations where a-c to d-c conversion equipment must be purchased for the job, the cost of the variable voltage equipment is very little if any more than that of the d-c rheostatic scheme. Maintenance cost of the variable voltage scheme is generally recognized to be less than that of the alternate one.

CONCLUSION

The simple two motor hoist with totally enclosed gears should have preference in any bridge application. A new design of turntable has been devised so that the advantages of this hoist can be retained in those applications where the bucket must be rotated in its operation. Simplification of the cumbersome spring suspension and cradle type trolley drive is recommended. The proposal is to use a frame mounted motor with a totally enclosed axle hung gear case and a rubber mounted axle suspension scheme. The more simple but more reliable friction or spring type trolley buffer used with properly designed and maintained "slow down" and "final stop" limit switches is believed to be the best answer to the safety problem involved with the stopping of the trolley. The variable voltage control scheme has definite advantages which make its use justified on new bridge installations. The use of welding provides a structure which is more readily cleaned and protected from corrosion. There should be no question about the advisability of using it on pier and shear legs of a bridge, but its use on the heavily stressed span members should be accompanied by a careful study of the fatigue strength of the joints.

DISCUSSION

PRESENTED BY

MARC A. DE FERRANTI, Manager, Materials Handling Div., General Electric Co., Schenectady, N. Y.

B. H. KERSTING, Engineer, Wellman Engineering Co., Cleveland, Ohio.

GEORGE F. WOLFE, Project Engineer, Power Department, Dravo Corp., Pittsburgh, Pa.

M. A. de Ferranti: We are particularly interested in the author's comments on the use of adjustable voltage drives for the hoist and trolley motions of man trolley bridges. For the size of drive motors required for the main drive of some of the new large ore bridges and unloaders, it is almost imperative that the adjustable voltage system be considered. With the use of constant potential 230-volt, d-c supply and conventional rheostatic control, the size and number of contactors required call for excessive space and weight requirements for the electrical equipment. Table I shows a comparison of the weight and space required for electrical equipment on the man trolley of a bridge operating with d-c rheostatic control, and on the man trolley of a bridge operating on the adjustable voltage system. You will notice that the use of adjustable voltage reduces the space requirement for electrical equipment to less than half that required for a d-c rheostatic drive, and that the weight of the electrical equipment on the man trolley of an adjustable voltage drive is reduced to approximately one-third of the weight required for the electrical equipment on the man trolley of a d-c rheostatic drive.

This figure also shows that in making a comparison between the cost of using adjustable voltage drive and d-c rheostatic drive for an ore bridge, it is misleading to think only in terms of equipment actually on the ore bridge. In considering a new installation of ore bridges, it is necessary that all of the electrical equipment back to the high voltage power supply be considered. For

example, in the comparison of Table I, the cost of electrical equipment installed on the ore bridge is considerably higher for adjustable voltage than for d-c rheostatic drive. However, the very much reduced cost of an a-c substation and distribution system as compared with a stationary a-c to d-c conversion substation and a 230-volt, d-c distribution system changes the picture. The net result is that the total cost per horsepower installed on an adjustable voltage driven ore bridge installation is approximately 15 per cent less than for a d-c rheostatic installation.

In addition to these figures, some consideration must be given to the benefits which the ore bridge manufacturer can gain from reduced weight and space of electrical equipment on the man trolley. It should also be pointed out that the adjustable voltage system permits the use of increased armature voltage over the normal voltage rating of mill motors, and thereby makes additional capacity available from the motors. This not only allows the use of physically smaller motors than rheostatic controlled machines, but gives the inevitable gains from lower inertia driving units.

It must be emphasized, however, that in many cases where new ore bridges are being added to an existing installation for which there is an adequate supply of d-c power, adjustable drive may not be justified. Similarly, many modernization programs, because of existing d-c power supply, will plan on reusing the present system of drive for their ore bridges and unloaders.

TABLE I

Comparison of d-c rheostatic and adjustable voltage drives for man-trolley ore unloaders

	D-c rheostatic	Adjustable voltage
Space required on man-trolley for control for bucket hoist and trolley drives	425 cu ft	200 cu ft
Weight of control installed on man-trolley for bucket hoist and trolley drives	13, 500 lb	4000 lb
Installed cost per hp (in dollars) all electric equipment on unloader*	105	145
Installed cost per kw (in dollars) of substation for unloader*	100	20
Total installed cost per hp of electric equipment for complete installation*	185	160

*Based on author's companies estimates for similar installations.

George F. Wolfe: Eight years ago I delivered a paper before the AISE and prophesied in it we would have the all-welded ore bridge. Since then I have had occasion to change my mind. I agree with Mr. Rose on complete welding of the trolley, the trucks, and the legs, but not on the span.

The thing I want to point out is that while we have advanced enormously in welding, there is no data presently available which permits any designer to design safely a truss for a welded bridge unless he can eliminate all fillet welding. If anyone can design a truss 100 per cent butt welded, he will have a truss superior to any riveted structure, but it is impossible to get your lateral bracing and transverse framing into a bridge and not do some type of connection other than butt welding.

B. H. Kersting: While some of the author's recommendations are a departure from past practice, it is obvious, however, that the elimination of springs and cradles together with the saving of weight expected from the elimination of certain electrical equipment as discussed by Mr. de Ferranti would reduce the dead weight of the trolley considerably. This reduction in trolley dead weight will without doubt reflect advantageously on the initial as well as on the operating and maintenance cost of the bridge. I am also interested in the availability of totally enclosed "Unit Cooled Mill Type Motors." I mean a blown motor where the independently blown air from the motor passes over an inner cooler or heat exchanger and is thereby cooled and returned to the motor by the motor blower. The cooling system would be similar to that used for the new type unit cooled standard d-c motors, as advertised in the Iron and Steel Engineer magazine. By reason for asking this question is that we have lately received several inquiries and specifications for ore handling equipment for steel mills wherein the purchaser specifies this type of motor, and we had to resort to makeshift fillers and blowers to meet the requirements of purchasers' specifications. The raw unfiltered air should not be used for cooling of the motors.

Referring to the part of Mr. Rose's paper dealing with trolley travel safety stops, etc., I would like to offer the following comments. In spite of all other safety devices, it is my experience that the installation of a simple and substantial trolley bumper of sufficient capacity to stop the trolley is still an important operating requirement. All the other mentioned safety devices, such as automatic slowdown, dynamic braking, Wilson Ritchie control, and solenoid brakes are connected to the axle drive and can only retard the speed but cannot stop a skidding trolley on wet or icy rails.

B. A. Rose: The information given Mr. de Ferranti in his discussion of the paper is a welcome addition in that it substantiates statements that were not fully developed.

Mr. Wolfe has apparently misunderstood the statements on welding because he disagrees with the welding of the span structure. I made no recommendation regarding welding of the span other than to say that if it is done it should be studied carefully to ensure that peak stresses in the connections do not exceed the material endurance limits. By his statements, I would conclude that he also is having difficulty in designing a fully welded span structure. I would hesitate to say that a completely welded span structure will or will not be built but I am convinced that welding of certain members of the span can safely be done and that its use in these cases will simplify the structure, making it less costly and more easily cleaned and painted.

Commenting on Mr. Kersting's discussion on the trolley bumper, I have to agree with him in his belief that a simple and substantial trolley bumper, capable of stopping the trolley in an emergency, is a desirable feature but I venture the opinion that he also finds such a bumper, capable of stopping the larger trolleys from speeds approximating 1000 fpm, without risk of injury to the operator, is not a simple device.

POWER TRUCK TRANSPORTATION IN STEEL PLANTS

By CHARLES S. SCHROEDER
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. . . . from an initial capacity of 2500 lb, fork trucks for steel mill service have grown to giant 60,000-80,000 lb units for handling coils of strip . . . .

▲ A great many changes have been made in the steel industry during the last twenty years. Steel management has been courageous and farsighted in making huge capital investments at considerable risk in developing techniques that have held the basic price increase in steel considerably below the cost increase of labor. This has only been accomplished by mechanizing to the fullest, all of the processes in its manufacture.

Probably the greatest fundamental change has come through the employment of continuous processes—running sheet continuous on a strip mill, making plates larger and longer, running coil rod continuous, drawing wire on multiple benches, rolling longer bars and shapes, so that all the processes are relatively more continuous.

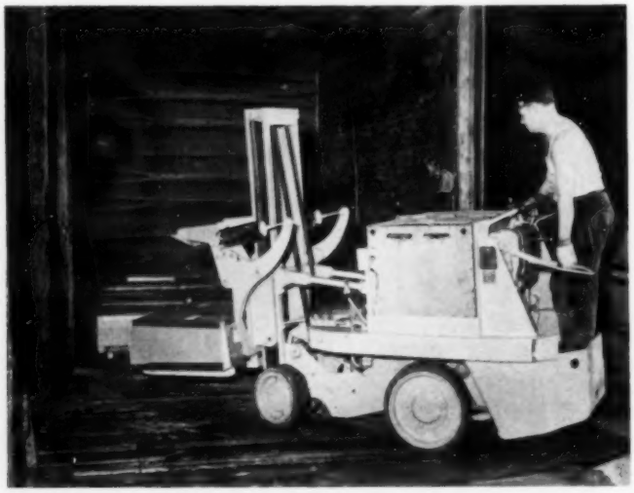
The electric truck industry as a whole has given full and practical cooperation in applying development to their product to meet the requirements that this technological advancement has brought about. It should also be added that steel engineers are exceedingly ingenious in conceiving both the question of new uses of industrial trucks as well as the basic design of the trucks themselves. Many of the basic principles of truck elements were developed by steel company engineers.

The most recent advance in steel sheet mill operation is the introduction of larger coil units. It appears that 60,000-lb coils will soon be common practice in the industry. These larger coils are really an amplification of making processes more continuous. The reduction in cost of re-threading large, five-stand mills, plus the cost of waste material at the beginning and end of each coil, points to the advantages that may be obtained by running the units larger and increasing the speed of mills.

From the standpoint of truck design it is our opinion that a machine of this capacity is practical and should operate at less cost per ton handled than would be the case with smaller units in a high capacity continuous

Figure 1 — When fork trucks were first used in steel plants, they were normally handling small light loads.

Figure 2 — Lift trucks were particularly useful in loading box trucks.



mill. It would seem a practical assumption that plants can be organized and arranged to provide maneuvering space for the largest practical unit. However, if we cramp the size of the machine, through the use for example of undersize tires, restricted overall length or similar physical restrictions, we will place greater strains on the truck, limitations on its use or value, and inevitably increase maintenance. The industry should allow the use of sufficient rubber and liberal dimensions in the machine itself.

It also appears to be practical to arrange these trucks so that when smaller coils are handled the machine will be capable of carrying two or more coils per load instead of one large coil. By such an arrangement, the heavy capacity of the machines could be utilized to the fullest extent.

It is believed that the biggest problem that will arise from heavier capacity equipment is that of floor strength. In a number of sheet mills, the floors are only 7 or 8 in. thick, and in some cases lie on filled undersoil. A reinforced floor of this thickness does not appear strong enough for the weight involved.

A study was made by a firm of architectural engineers, and it was their recommendation that the floor should be at least 14 in. thick when laid on soil that has a bearing capacity of 500 lb per sq ft. If the undersoil were swampy or fill, the floor would have to be heavier still.

There has also been some difference of opinion of the value of wood block floor over concrete in this type of mill. I have noticed some operations where the wood blocks have been shifted in large areas over the floor due to the braking action and accelerating action of the truck wheels. It is possible that lower maintenance in trucking areas would be practical by the use of a hard top surfacing, which would stay put under the severe condition imposed by heavy equipment, with the maximum use of steel for reinforcing and foundations.

Another type of heavy duty equipment that is being considered by some mills is for transporting heavy rolls from the strip mill to the machine shop for service. Some of these loads would run as high as 100,000 lb. In most cases they are now transported by narrow gauge, but the added flexibility that is inherent to rubber tired floor transportation has attracted the attention of operators, and it appears likely that equipment of this character will be installed. The flexibility of a heavy duty tractor pulling a trailer may show definite advantages in operation.

It is not our purpose to discredit in any way the other basic methods of handling material, but rather to point out the advantages of industrial trucks so that these factors will be considered when choosing a method of handling.

Types of machinery available for major handling operations in the steel industry, other than that for bulk and for fluids, are as follows: Overhead cranes, conveyors, industrial railway and power trucks, each of which have their proper function and place, and in general are well applied to the specific problem involved. There is one characteristic, however, that rubber tired equipment has which the others do not possess, and that is the matter of flexibility. The fact that a power truck can operate wherever it has a proper floor gives it the unique advantage that it has over all other methods.

At the beginning of a plant layout, this characteristic does not loom up with great importance because the plant is usually laid out so that all major material remains within the confines of a predetermined area or building. In time, however, it is often found that market conditions change something that alters such a well laid out system. It may be a change in tonnage of output; it may be a change in the size of the product; it may be a change in its processing. Any of these changes may make it necessary to move the material to a location not originally planned for. Material may have to be brought to another building or to the yard, or to an inaccessible part of the same building. It is when such a situation arises that the industrial truck system displays its extra advantage of flexibility.

To some this may not sound important. We sometimes feel that our mills are right up to date and that major changes will not be necessary. On the other hand, if we just look back at the really fine plants that are in operation today and compare their activity with that of ten years ago, I believe every one of us will agree that changes have been made, even though these mills when built were laid out without stinting cost and with in-

Figure 3 — The ability to lift the load as well as to move it is one of the characteristics of the lift truck.

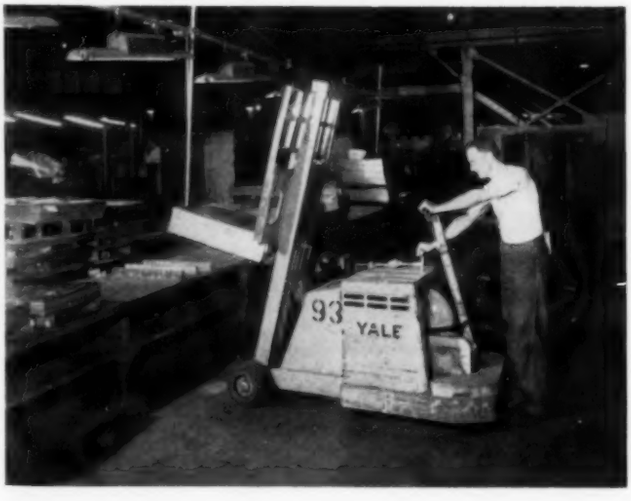


Figure 4 — The development of palletizing made the use of lift trucks a very efficient operation.

telligence and ingenuity. In spite of this, new ideas came into the picture that changed routing of material, or changed shape, size or some other characteristic that required an alteration in the handling problem. In plants that employed industrial trucks as their material handling medium, these changes came comfortably, were made quickly, and seldom involved additional cost of operation.

Another advantage that comes with power trucks lies in its flexibility when equipment goes out of service for repairs. Usually it is possible to have stand-by equipment for a relatively large number of units, that can step into the breach when one piece of equipment needs repairs. The unit that is out of service does not block operations by being in the path of material handling motion, but instead is brought to a service garage where it can be cared for. I grant that such conditions do not develop often, but when they do a real problem is posed.

The broad acceptance by the steel industry of power trucks for heavy operation, has until recently, been confined to smaller units. Such operations as handling of tinplate, rod coils, wire, nails, etc., were about the only real activity in handling steel mill product. Up to the present moment there appears to be no alternate for this system, and I believe it is doing eminently well in all its applications.

The use of the heavier equipment, however, has only become general in relatively recent times. Since the early days of this heavy equipment, the steel industry and the truck industry have learned much in the design of equipment. The experience gained from the earlier machines has pointed the way to improvement, and it will be found that operating costs per ton handled have definitely gone down as a result of this. One of the first important improvements that were made in this type of operation was the use of time delay, nonplugging, accelerating electric control. Incidentally, this was first suggested by a steel operator, who not only suggested it but worked out the control in detail. Many other improvements too detailed to mention, have been made with the close cooperation of steel mill engineers, and when you are comparing operation cost records, it is important to segregate the old equipment from the new in order to avoid a misleading result. As time goes on, further improvements will be made, as the industry is never stable.

Further improvement can come from proper maintenance of road surfaces. We would not think of using railway tracks that were bumpy or uneven, they would immediately be repaired. The same can be said for crane runways, they must be properly maintained. In many cases, however, we will neglect proper floor repair merely because the truck equipment will run over it, but we completely disregard the fact that such road surface will have a definite bearing on the maintenance of rubber tired equipment, both as regards the tires themselves and the mechanism of the vehicle. Adequate floors in today's scheme of operation mean much more than they ever did before. In the old days flooring was not much more than a walking and storing surface, but today it should really be designed as a part of the plan, and a very vital one, as you can never tell when it may be called upon to do more than was originally planned for. It is very advisable to design new buildings and new plant road surfaces for ample capacity, as it pays in the long run.

The use of the smaller equipment has been well established in all mills. The handling of tinplate, wire rod, wire coils, nails, rivets, etc., is now almost universally done with power equipment.

In addition to this, however, some special truck applications which we call "gadgets" may have applications in miscellaneous operations. This includes such devices as scoop trucks, hydraulically operated clamping devices, rotators, crane trucks, etc., that have been originally designed for activities other than that found in large steel mills. Such equipment may not find uses in the basic product, yet can show excellent savings on maintenance work, supplies, etc. For example, the handling of fire brick is a big problem in steel mills. We are now developing a machine which will clamp these bricks to hold them in transit from the storage area to the maintenance job of relining the furnace. It is hoped it will not only save labor of handling, but will also reduce damage to the brick itself.

Figure 5 — Bundles of wires can be easily picked up, moved and piled by the lift trucks.

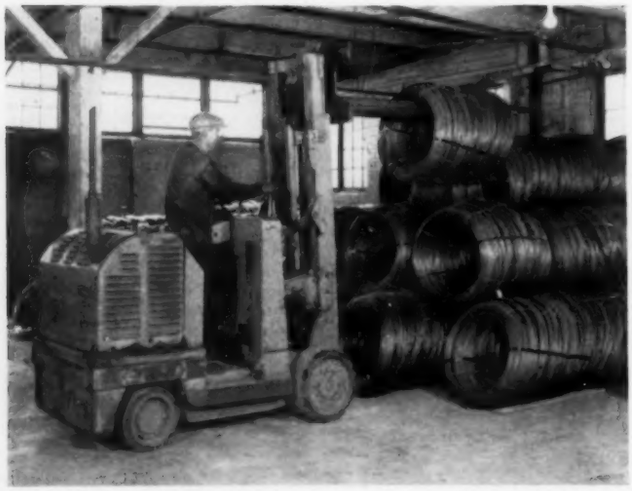


Figure 6 — Coil handling by the use of lift trucks is a common operation in the steel plant.

THE MIDLAND WORKS
of
CRUCIBLE STEEL CO. of AMERICA

THE MIDLAND WORKS *of* CRUCIBLE STEEL CO. *of* AMERICA

By T. J. ESS

▲ THE Midland plant of Crucible Steel Co. of America, located on the Ohio River, was originally the Midland Steel Co., which began operations as a single blast furnace plant in 1906. In 1911, the company was purchased by Crucible Steel Co. of America, which had been formed in 1900 by the merger of 16 steel companies engaged principally in the production of alloy and tool steels. Acquisition of the Midland plant gave Crucible basic producing facilities to supply its various specialty plants.

Over the years the Midland plant has been expanded and improved, until it now comprises a completely integrated unit designed for the production of a wide range of high quality, specialized products, supplying the primary material for other divisions and subsidiaries of the company. Products of the Midland plant now are pig iron, coke and coking by-products, stainless, alloy and special carbon steels. Rolled and formed products include ingots, blooms, billets and slabs; hot rolled bars, rods and special sections of forging stock; cold finished bars, turned rounds, centerless ground rounds and drill rods; stainless sheets and strip; agricultural discs, sheared and blanked shapes, agricultural plates and colters.

RAW MATERIALS

High volatile coal comes principally from the company's own mines in Greene County, Pa., on the Monongahela River, and is transported by barge to the plant, where it is unloaded by a bucket and cable hoist rated at 350 tons per hr. The bucket dumps into a bin which feeds on to a 42-in. belt conveyor more than 550 ft long which carries the coal to a junction tower, from where it may be moved over belt conveyors directly to the breaker and mixer building, or to a bin from which railroad cars may be filled if it is desired to move coal into the storage yard or to other parts of the plant.

This coal, from the Pittsburgh seam, is washed at the mine, with the primary product going for metallurgical use and the secondary product for steam. Low volatile coal for the coke plant is purchased, as is some additional coal for gas producers and boilers. This last coal, which is received principally by truck, can be screened in the plant, if necessary, the portion over 1½ in. going to gas producers and the smaller sizes to boilers.

Coal arriving by rail is unloaded into track hoppers and is carried by belt conveyors to the junction tower previously mentioned.

Coal requirements of the plant are approximately 2700 tons per day of metallurgical high volatile, 300 tons per day of low volatile, and 1000 tons per day of steam and gas producer coal.

Iron ore comes principally from the Mesabi range, where the company owns a half-interest in extensive reserves. Arriving at the plant by rail, the ore may be unloaded on the high line directly into the ore bins, or by car dumper and bridge into the ore yard.

About 58,000 gross tons of ore, 36,000 net tons of coke, 12,000 gross tons of limestone, and 5,000 gross tons of dolomite per month are required for full operation.

Storage for the raw materials is provided by a yard approximately 1800 ft long, served by one car dumper and two 12-ton bridges. Capacity for 450,000 gross tons of ore, 110,000 tons of metallurgical coal, 50,000 tons of steam and gas coal and 20,000 tons of fluxing material (limestone and dolomite) is available.

COKE PLANT

Coal handling equipment for the coke plant is designed for 250 tons per hour, and includes a breaker, a hammer mill, four 150-ton mixer bins and two oven bins of 1500 and 1800 tons capacity, with the necessary connecting belt conveyors. After the coal is crushed to about 1½ in. in size, it is conveyed to the mixer bins, two of which hold high volatile coal and two low volatile coal. Belt conveyors take coal from these bins and mix it according to the desired proportions, which is usually 90 per cent high volatile and 10 per cent low volatile. At the mixing junction, one-half gallon of oil per ton is sprayed on the coal to increase bulk density of the oven charge. The coal mixture then flows to the hammer mill, where it is pulverized so that about 70 per cent will pass through a ⅛-in. screen. Belt conveyors then move the coal to the oven bins, from where four-hopper, 465 cu ft charging larries carry each charge to the oven.

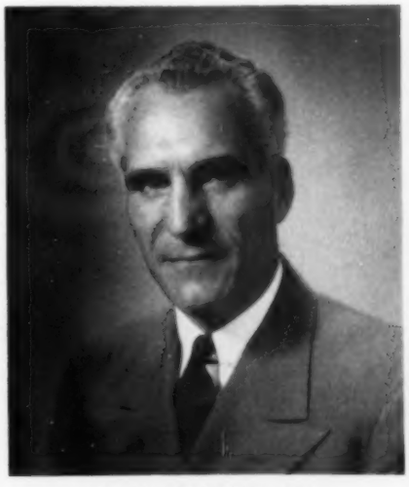
Coke ovens are grouped in four batteries, two of 50 ovens each, one of 21 ovens, and one of 63 ovens. The first two batteries are of cross-regenerative type, while the last two are of cross-flow, combination low-differential design. The ovens are 15¾ in. wide on the pusher side and 18¼ in. wide on the coke side. They are 37 ft long x 9 ft 10⅝ in. high and provide for a volume of 465 cu ft of coal, taking a charge of 11.7 net tons of coal each. The two 50-oven batteries are fired with a mixture of coke oven gas and blast furnace gas running about 430 Btu per cu ft, while the other two batteries use straight blast furnace gas or coke oven gas.

Two pusher machines serve to move coke from the ovens into one of three 10-ton side dump quenching cars, which are moved by electric locomotives to either of two quenching stations. After quenching, coke is dumped on one of two cooling wharves, from where it is fed on to a belt and conveyed to the screening station. Crusher and shaker screens separate the coke into furnace coke, (over a 1⅜ in. screen), nut coke (through 1⅜ in. screen, over ⅞ in. screen), pea coke (through ⅞ in. screen, over ⅝ in. screen), and breeze (through a ⅝ in. screen). Furnace coke is generally carried on belts to a bin, from where it is dropped into an electrically driven hopper car which carries the coke to the bins under the high line of the blast furnaces. Furnace coke and the smaller sizes can be loaded into railroad cars if desired.

Coal is unloaded from barges by a bucket and cable hoist, and then carried away by belt conveyor.

A complete new by-product and benzol plant was installed in 1948. The by-product plant contains five indirect type primary coolers, two turbo exhausters, one turbo booster, two positive displacement boosters, two electro-static tar removers, tar collecting and storage tanks, two units for the production of ammonium sulphate, one ammonia still and one dephenolizing tower.

W. P. SNYDER, JR.
CHAIRMAN



W. H. COLVIN, JR.
PRESIDENT

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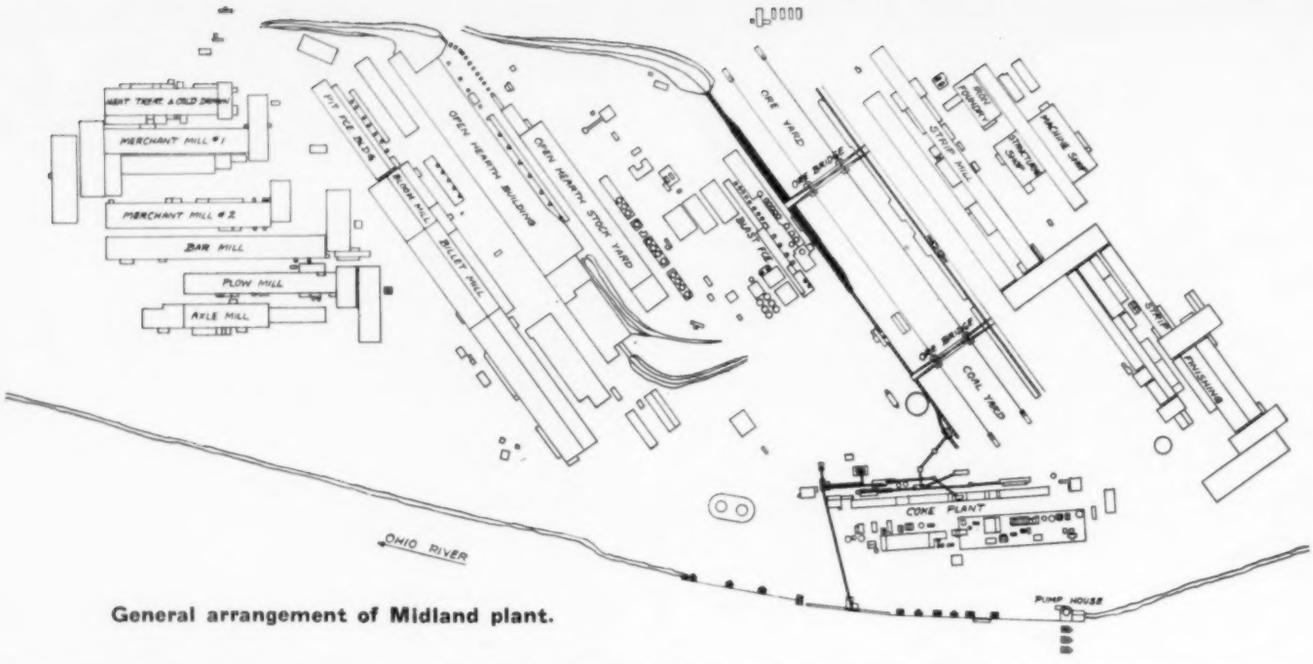
VICE PRESIDENT, OPERATIONS



General arrangement of Midland plant.

The benzol plant contains two final coolers (one of which has a tar absorption system), two water cooling towers, two benzol washers, one wash oil purifier, one wash oil still with vapor-to-oil heat exchanger, one light oil rectifying column and condenser, one carbon disulphide column, one batch type crude still, two batch type pure stills, two agitators, wash oil coolers, and the necessary tanks and pumps for the recovery and processing of light oil products. Facilities permit the shipment of benzol by tank car truck or river barge, while toluol, xylol and intermediate light oil can be shipped in tank cars or trucks.

Normal operating schedule calls for 231 ovens pushed per day, or a gross time of about 19.1 hours, coking 2700 tons of coal. Maximum capacity is 270 ovens per day, or about 16.3 hr gross coking time. Coke yields range 67 per cent furnace coke, 3 per cent nut coke, 2 per cent pea coke and 4 per cent coke breeze. By-product yields are about as follows:

	Per ton of dry coal
Coke oven gas	11,000 cu ft
Tar	10.5 gal
Ammonium sulphate	23 lb
Light oil	3.0 gal

Coke is produced in 184 by-product ovens having a normal coking capacity of 2700 tons of coal per day.

The light oil is fractionated into 1.95 gal of benzol, 0.45 gal of toluol, 0.15 gal of xylol and 0.15 gal of intermediate light oil per ton of coal coked.

Coke oven gas, averaging 570 Btu per cu ft, is used in a mixture with blast furnace gas for underfiring some of the coke ovens, as previously mentioned. This mixing is effected by an interconnection of lines carrying the two gases, with suitable control valves. The resulting mixture is controlled by continuous calorimeters. Surplus coke gas is piped to the steel plant, where it is used as fuel in the open hearth, No. 2 merchant mill, strip mill, boilers, etc. Approximately 24,000,000 cu ft per day is consumed by these departments. A 20,000 cu ft coke oven gas holder and a 1,000,000 cu ft blast furnace gas holder are installed on the respective gas systems.

At the steel plant, a gas mixing station is installed wherein natural gas and air are mixed so as to give a resultant Btu per cu ft approximately equal to that of the coke oven gas, so that shortages of the latter are made up by a mixture that can be used without upsetting control operation.

BLAST FURNACES

Two blast furnaces produce basic iron for use in the open hearth department. The analysis of this iron averages approximately as follows:

	Per cent
Silicon	1.00
Sulphur	0.032
Phosphorus	0.154
Manganese	1.60

Principal proportions of the blast furnaces follow:

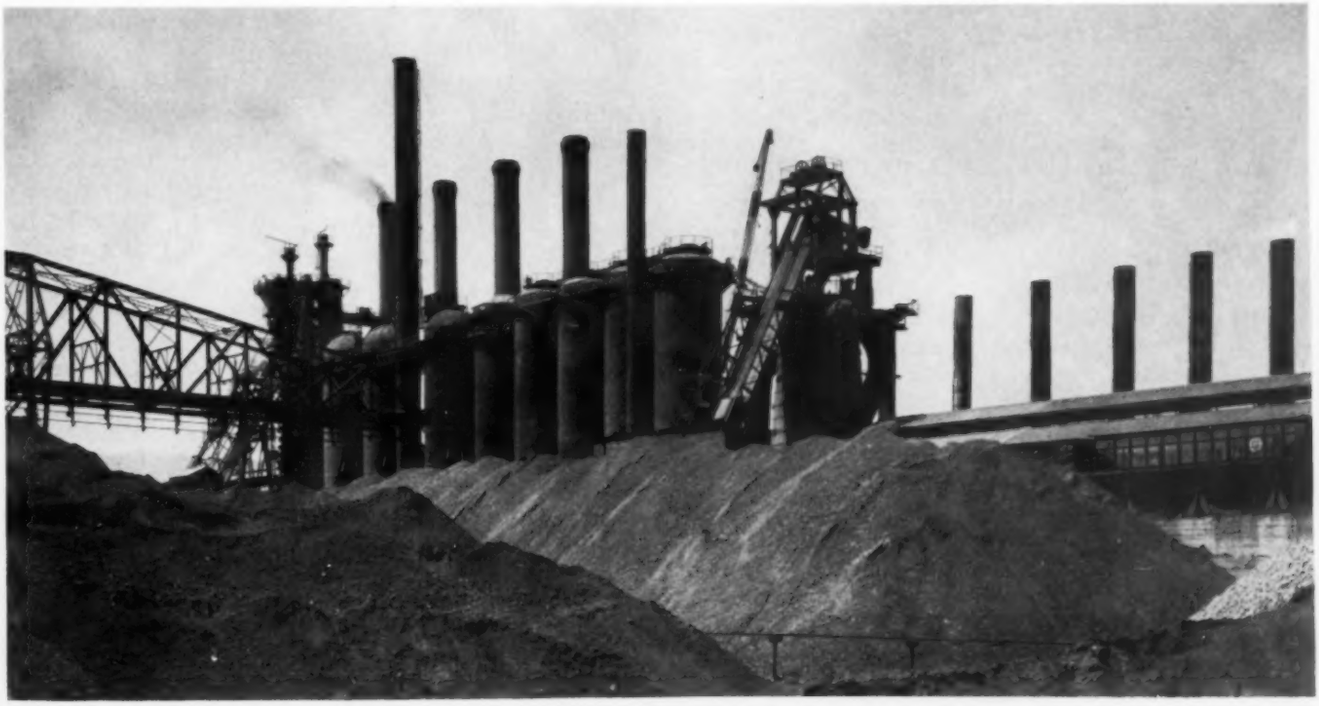
	No. 2	No. 3
Diameter of hearth, ft-in.	18-0	18-0
Diameter of bosh, ft-in.	22-10¾	22-6
Diameter of stockline, ft-in.	16-9	16-0
Height, iron notch to top ring	83-0	91-3
Height of crucible, ft-in.	10-6	9-9
Height of bosh, ft-in.	14-8¼	12-3
Height of straight section, ft-in.	8-6¾	8-0
Height of inwall section, ft-in.	38-0	43-9
Height, stockline section to top ring, ft-in.	15-11½	18-3
Height, bottom to iron notch, ft-in.	1-7½	0-9
Height, iron notch to cinder notch, ft-in.	4-3	4-6
Height, iron notch to tuyeres	7-6	8-0
Working volume, tuyeres to stockline, cu ft	20,740	21,507
Bosh angle, deg-min-sec	80-32-0	79-35-35
Inwall slope, in. per ft	1⅛	0.89
No. of tuyeres	10	12
Lining thickness, crucible, ft-in.	2-7½	2-7½
Lining thickness, bosh, ft-in.	2-7½	2-7½
Lining thickness, stack, ft-in.	3-4½	3-0
Lining thickness, throat, ft-in.	3-4½	3-0
Big bell diameter, ft-in.	12-0	12-0

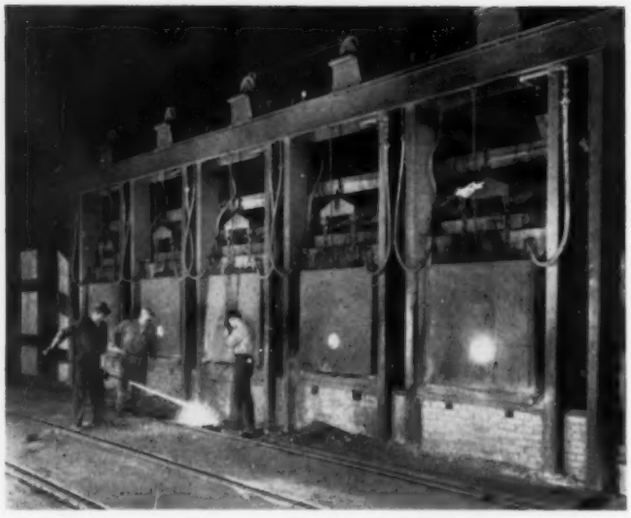
Both furnaces are cooled with water-cooled steel hearth jackets and bronze cooling plates in the bosh. Cast steel wearing plates protect the stocklines.

Each furnace is provided with four two-pass side combustion hot blast stoves. Those on No. 2 furnace are 21 ft 3 in. x 105 ft, but differ somewhat in construction and range from 73,765 sq ft to 122,105 sq ft in heating surface, averaging 86,980 sq ft. Checkerwork is of basket weave and open joint design, with flues 4 x 4 in. and 3 x 3 in. The stoves on No. 3 furnace are 23 ft 1 in. x 105 ft, with basket weave checkerwork and 4¾ x 4¾ in. flues. Three of the stoves have heating surface of 96,700 sq ft each, while the fourth has 78,285 sq ft.

The stoves are equipped with automatic proportioning pressure burners, operate on a cycle of six hours on

Two blast furnaces produce approximately 1370 gross tons of iron per day.





This 140-ton unit is one of those completely rebuilt as part of a program of enlargement which will ultimately include all open hearth furnaces.

gas, two hours on blast, and consume approximately 40 per cent of the total blast furnace gas make, or about 8000 cfm of gas per stove. Stove stack temperature averages 500 F, while blast temperature averages about 1200 F. Automatic blast temperature control is provided on No. 2 furnace, but not on No. 3.

Blast volume averages about 46,000 cfm and is supplied by one cross-compound horizontal blowing engine rated at 720 cu ft per revolution and four horizontal engines rated at 360 cu ft per revolution. All of these engines operate on 175 psi steam and are equipped with barometric condensers.

Blast pressure generally ranges 16-18 psi, while furnace top pressure normally runs 40 in. water column.

Gas leaving the furnaces at temperatures of about 300 F passes through dust catchers, where dust content is reduced to about 35 grains per cu ft. Of this gas, about 75 per cent then passes through a wet washer of 90,000 cfm capacity, where the dust content is reduced to about 0.10 grains per cu ft. Approximately one-fourth of the wet-washed gas is then put through a two-chamber electrical precipitator, which cuts the dust content to 0.0025 grains per cu ft. The gas cleaned by precipitation goes to the coke plant for underfiring two batteries of ovens. Part of the wet-washed gas is used on the hot blast stoves, with the remainder going to boilers along with some gas processed only through the dust-catchers.

Water from the washer goes to a settling pond in the ore storage yard. The sludge is reclaimed from the pond by the ore bridge, and together with the dry flue dust, is sintered in a pan-type sintering machine with a capacity of 250 tons per day.

Each furnace casts five times per day, the iron running into 65-ton open top ladles, which are then moved to the open hearth and dumped into a 500-ton hot metal mixer. If iron is not needed at the open hearth, it can be put into pig form over a double strand pig machine of 65 tons per hr capacity.

Slag from the furnaces (averaging about 1055 lb per gross ton of iron) flows into ladles and is moved to a slag dump, where it is reclaimed and graded by an outside company.

Both furnaces have electrically operated double skip hoists and revolving distributor tops, with manual control. The bells on No. 2 furnace are steam-operated, while those on No. 3 are pneumatic. The charging sequence normally used is OOSCCC — dump big bell. Coke is charged by volume, ore and stone by weight.

Charging and performance data are as follows:

	Lb per gross ton of iron	
	No. 2	No. 3
Iron ore	2490	2980
Scrap	400	400
Roll scale	600	300
Sinter	245	245
Open hearth slag	100	100
Limestone (3-6 in. in size)	930	1075
Slag produced	1010	1100
Flue dust made	100	270
Furnace scrap made	45	45
Coke used (wet)	1770	1840
Coke used (dry)	1700	1776

Average analysis of slag is somewhat as follows:

	Per cent
SiO_2	32.60
Al_2O_3	13.50
CaO	45.00
MgO	6.00
S	1.80
Fe	0.50
MnO	1.00

Iron production averages 670 gross tons per day from No. 2 furnace and 700 gross tons per day from No. 3. Record production from the two furnaces are respectively 910 and 990 tons per day.

STEELMAKING

Open hearth capacity (793,200 net tons per year) is provided by eleven stationary furnaces, two of which are rated at 140 tons, with hearths 38 ft x 15 ft, and nine at 132 tons, with 35 ft x 14 ft hearths. A program of enlargement of all furnaces is now in progress. The furnaces are 70 ft long overall, and are spaced on 82 ft centers. Furnace hearths, which are about 34 in. thick, are at present divided between sintered and rammed bottoms, with the latter going in as replacements are needed. In this construction, the hearth consists of a one-inch layer of insulating concrete, a layer of fire brick ranging from 9 in. at the ends to zero near the center, a 13½-18 in. layer of chrome-magnesite brick, about 12 in. of rammed magnesite and a 3 in. sintered layer of magnesite. Backwalls are of sloping construction, and the sprung arch roofs are 12 in. thick with 15 in. ribs, with the thickness increased to 15 in. at the shoulders. Outside of the hearth, basic brick is used in the front walls, blocks, ports, bridgewalls, and end bulkheads, with the other parts above the floor level of silica brick.

Downtakes are 8 ft long x 5 ft 1½ in. wide, giving a total area of 82 sq ft at each end of the furnace. Slag pockets are 13 ft 4½ in. x 16 ft.

Regenerator chambers, 26 ft 9 in. long x 28 ft 3 in.

wide, are of double construction with sprung arch roofs forming two chambers, each 11 ft 4 in. wide. Checker volume total 6000 cu ft on each end of the furnace. Checker flues are 7¼ in. x 7¼ in. in all furnaces. Furnace stacks are 185 ft high, and 12 ft in diameter at the base.

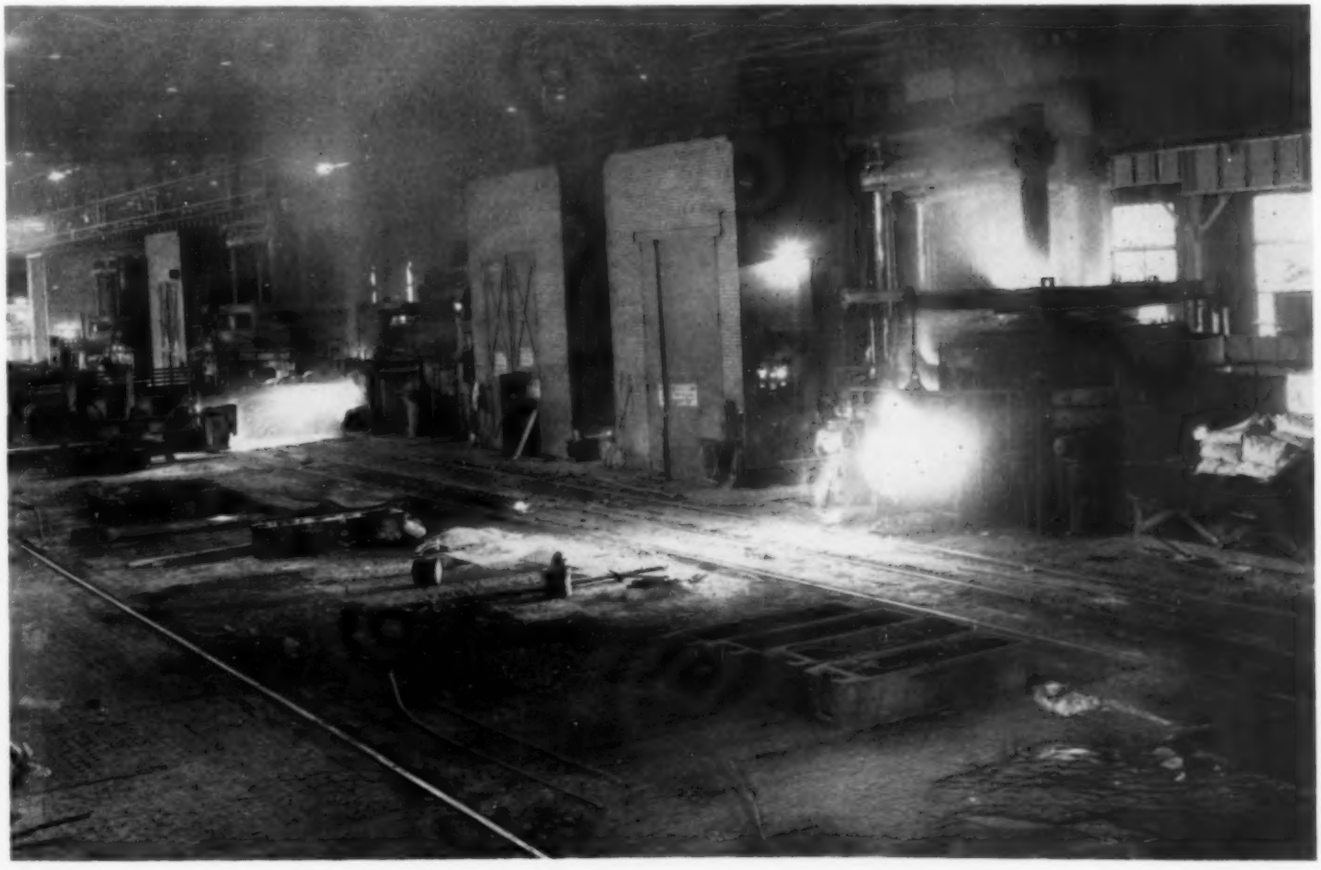
Open hearth fuel consists of about 30 per cent coke oven gas and 70 per cent liquid fuel. The latter may be either fuel oil or pitch. Normally, fuel oil consumption is about twice that of pitch. Fuel is introduced through combination dry burners, with liquid fuel and steam entering a mixer and passing through a one-inch pipe which is placed concentrically within a 4 in. pipe through which the gaseous fuel flows. The one-inch pipe carrying the atomized liquid fuel stops 3 in. short of the end of the outer 4-in. pipe. The burner extends into the furnace through a double-walled cooler fabricated of steel plate and staybolts, through which water circulates.

Two furnaces which have already been enlarged are completely equipped with automatic controls on furnace pressure, fuel-air ratio and furnace reversal, and are provided with forced draft fans rated at 15,000 cfm at 1½-2 in. water pressure.

Fuel oil is delivered to the plant by barge, and pumped into either of two 420,000 gal tanks located on the river bank. The oil is then pumped into 160,000 gal tanks adjacent to the open hearth. There are five of these tanks, handling between them fuel oil and pitch. Two 9 in. x 5½ in. x 12 in. duplex steam-driven pumps

General view of open hearth pouring bay, showing teeming of heat at right. Ladle repair pits and facilities for making steel castings are in the foreground.

Six electric arc furnaces produce a wide range of high quality alloy steels.



rated at 10,000 gal per hr circulate the oil through the open hearth, while two 10 in. x 6 in. x 12 in. duplex pumps rated at 15,000 gal per hr are provided for the circulating pitch system. The open hearth storage tanks are equipped with steam coils which heat the oil to 140 F. From the pump house to the open hearth, oil lines are wrapped together with pitch lines and tracer steam lines, further raising liquid fuel temperature to 180 F. Two furnaces are also provided with individual oil preheaters.

Fuel input is maintained at 52,000,000 Btu per hr during meltdown, reduced to 47,000,000 Btu per hr when the hot metal is added, further cut to 40,000,000 Btu per hr during the lime boil, and restored to about 47,000,000 for the working period. Fuel consumption averages 4,300,000 Btu per ton of ingots.

Steel is produced in a wide variety of carbon and alloy grades. Charges total about 300,000 lb and consist of about 40 per cent scrap, 57 per cent hot metal and 3 per cent cold iron. Hot metal is brought from the mixer to the furnaces in ladle cars hauled by a 35 ton diesel locomotive. Scrap is composed of crop ends and pit scrap, supplemented with purchased scrap. Iron analysis averages 1.0 per cent silicon, 0.033 per cent sulphur, 0.150 per cent phosphorus, and 1.60 per cent manganese. Fluxes, consisting principally of limestone with some burnt lime and fluorspar additions, total about 162 lb per ton of ingots produced.

Time of heats averages 11.6 hr, tap to tap. A bogey of 45 min is allowed for makeup time, and everything beyond that is considered delay. A traveling dolomite machine is used in making up furnace bottoms. Furnace output averages 12.0 tons per furnace hr, tap to tap, and 14.1 tons, charge to tap.

Steel is tapped into elliptical ladles of 140 tons capacity. These ladles have replaced the original 115-ton ladles as furnace capacity was increased.

Ingots are principally of big-end-up type, in 24 in., 26 in., or 27 in. squares, and 32 in. x 38 in. rectangular, ranging 9500-24,000 lb in weight. Some big-end-down slab type ingots, 22 in. x 54 in. and 22,500 lb in weight, are also produced. Ingot molds are cleaned by water sprays and then sprayed with powdered pitch or graphite before pouring.

Steelmaking facilities also include six electric arc furnaces. Four of these have tapered shells of 15 ft 8 in. diameter at the bottom and 18 ft diameter at the top. Each of these is supplied from a 10,000 kva transformer, and employ 20-in. graphite electrodes. One furnace has a 14 ft 3 in. diameter shell and is equipped with a 6000-kva transformer, while the sixth furnace is 12 ft in diameter and has a 4000-kva transformer. The two smaller furnaces use 14-in. electrodes. All furnaces are side-charged by two 10-ton floor-type charging machines except the 12-ft unit, which is top-charged. Transformers are water-cooled, and operate on a primary voltage of 11,000 with motor-operated tap changers to deliver secondary voltages of 118-240. No capacitor or added reactance is applied to the transformers.

On the primary side of each transformer is a 600-amp, 15-kv air circuit breaker and a gang operated disconnect switch.

Roofs of the arc furnaces are of silica brick 9 in. thick. Roof life averages about 52 heats. Sidewalls are constructed of metal-cased magnesite brick 18-in. thick, and last for approximately 250 heats.

All grades of electric furnace steel are produced, with double or single slag practice as required by the product. Heats range from 7 to 48 tons, and are turned out in approximately 8 hr, tap to tap. Annual capacity is 230,000 net tons per year.

The arc furnaces set up an average power load of about 15,600 kw, with a 15 min demand of about 25,000 kva. An overall power factor of 81 per cent is maintained. Power consumption averages 560 kwhr per ton of ingots produced.

In addition to regular grades of open hearth and electric furnace steels, some composite ingots are cast, wherein slabs of one analysis are inserted in the ingot molds and molten steel of another analysis is poured around the slabs. This process is used to produce composite or clad steels for soft center plowshares and similar products.

All of the steelmaking furnaces are housed in a building about 1800 ft long, consisting principally of two adjacent bays. The charging bay is 87 ft 5 in. wide, and contains two 75/25 ton hot-metal cranes and three 10-ton floor type charging machines for the open hearth, and two 20-ton hot metal cranes and two 10-ton floor type chargers for the electric furnaces. The pouring bay, 71 ft 8 in. wide, contains six pouring platforms and is served by six ladle cranes, three of 150-ton capacity, two of 75-ton capacity and one of 65-ton capacity, all equipped with auxiliary hoists.

This 40-in. blooming mill rolls blooms from 6 x 6 in. to 28 x 28 in. and slabs up to 40 in. wide, at an average rate of 105 tons per hour.

BLOOMING MILL

The primary rolling unit is a 40-in. two-high reversing blooming mill driven through 18-in. spindles by a 44 x 70 x 60-in., 125-rpm twin tandem compound reversing steam engine, operating on 160-psi steam pressure and equipped with a barometric condenser. The mill has a maximum delivery speed of 400 fpm and uses about 850 lb of steam per gross ton of steel rolled.

Mill pinions, of double helical type with cut teeth of 6.28 in. circular pitch, are 3.13 ft face width and run in babbitted bearings.

Mill rolls are 38 in. in diameter and have a 92-in. body length, with pass design varying according to the product to be rolled. The rolls run in babbitted bearings. The top roll is balanced by a counterweight, and is raised and lowered by 12-in. screws of 2-in. pitch, actuated by a single 150-hp mill type motor under magnetic control. Maximum roll lift is 44 in., and lifting speed may reach 17 fpm.

Side guards are provided on both sides of the mill, with manipulator fingers on the pulpit side only, and are driven through racks by four 150-hp mill type motors under magnetic control. Mill tables are driven through line shafts by mill type motors, all under magnetic control.

Mill scale is flushed hydraulically into a scale pit located in the adjacent bloom and slab yard.

Heating facilities for the blooming mill consist of ten blocks of regenerative soaking pits, each containing four holes 11 or 13 ft long x 5 ft 3 in. wide x 10 ft 6 in. deep. The pits are fired with producer gas, with combustion air supplied by a fan for each block of pits. Preheated air temperature runs approximately 900 F, and stack temperatures average about 750 F.

Ingots charged into the pits range from cold to 1700 F. Usual heating time is 5-6 hr, and fuel consumption averages 137 lb per ton of ingots heated. Two gas-fired furnaces are also installed for preheating cold ingots of certain "tender" grades of steel.

Two 7½-ton and one 10-ton pit cranes handle the ingots into and out of the pits, and an ingot car carries heated ingots to the mill approach table.

Ingots come to the blooming mill in a wide variety of sizes, ranging from 18 in. x 18 in. (4500 lb) to 32 in. x 38 in. (24,000 lb). Approximately 80 per cent of the steel rolled goes into blooms ranging from 6 in. x 6 in. to 28 in. x 28 in., with 20 per cent going to slabs 6-40 in.

This 24-in. bar mill produces rounds up to 8⅜ in. diameter, squares up to 9¼ in., and flats 1 in. x 6 in. and larger.

wide and down to 3 in. in thickness. The rolling rate runs from 20 tons per hr on 6 in. x 3 in. slabs up to 150 for large sections, and averages 105 tons per hr. It is planned to increase the proportion of slabs rolled on the blooming mill for rerolling in the strip mill.

Approximately 185 ft beyond the mill stand there is a steam-hydraulic shear capable of cutting sections up to 20 in. square. The shear gage measures lengths up to 25 ft. Crops from the shear drop into a scrap buggy which runs on a depressed track into the adjacent bloom and slab yard.

A parallel mill line connected to the blooming mill table by a transfer contains a 28-in., three-high motor-driven billet mill, driven through gearing by a 2500-hp, 148-rpm, 6600-volt wound rotor induction motor. This mill operates at a speed of 170 fpm, and produces billets 4, 5 or 6 in. square from 8 in. x 7 in. blooms in 3, 5 or 7 passes. A tilting table and a lifting table are installed on the entry and exit sides of the mill, respectively.

Leaving the 28-in. mill, billets move to a vertical shear, capable of cutting sections up to 64 sq in. and lengths up to 17 ft.

BAR AND MERCHANT MILLS

Three finishing mills provide facilities for a broad range of bar sizes, which form a considerable proportion of this plant's product.

Heating facilities for the bar mill consist of one continuous heating furnace 17 ft 9 in. wide x 42 ft 6 in. long, one one-way fired batch type furnace 17 ft x 23 ft, one one-way fired batch type furnace 17 ft x 15 ft 9 in., and two regenerative batch type furnaces 18 ft x 36 ft. The first three units are fired with coke oven or natural gas, while the regenerative furnaces burn producer gas, all under manual control. Fuel consumption averages about 4,000,000 Btu per ton of steel heated.

Heated blooms are drawn from the furnaces by two 3-ton overhead chargers and placed on an approach table 160 ft long.

The mill itself consists of three, two-high, 24-in. stands placed side by side and driven as a unit by a 5000-hp, 36-in. x 48 in., cross-compound reversing steam engine at 0-130 rpm. The engine exhausts to atmosphere, and consumes an average of 1200 lb of steam per gross ton of steel rolled.

Mill pinions are of herringbone design, with 14 teeth, 24-in. pitch diameter and 34-in. face. The roughing stand is equipped with motor-driven mill screws, and has a maximum roll lift of 10 in. The other two stands have manually operated screws.

Mill tables are motor driven through line shafts, and on the entry side of the mill the tables before the three stands are, respectively, 53 ft 6 in., 85 ft, and 109 ft long. On the exit side, the tables are 68 ft 6 in., 85 ft and 85 ft long, respectively. The tables have a maximum speed of 408 fpm. Cable-and-dog type transfers move the billets sideways from one pass line to another.

Hydraulic descaling sprays are located on both sides of No. 2 stand and on the entry side of No. 3 stand, and operate at 400-600 psi pressure.

Steel leaving the mill travels over a runout table approximately 100 ft long to a cooling bed 60 ft wide x 75 ft long. A 54-in. motor-driven hot saw, with

This merchant mill combines continuous, looping and cross-country layout in an arrangement giving a high degree of flexibility.

hydraulically operated carriage, is located in the runout table.

Blooms coming to the 24-in. bar mill may be of carbon, alloy, stainless or tool steel, and may range 1000-7500 lb in weight, 7½-15 ft in length, and 6 x 6 in. to 12 x 12 in. in cross-section. Product rolled may be rounds 2½-8⅜ in. in diameter, squares 2½-9¼ in., or flats 1 in. x 6 in. and larger. The average rolling rate is 30 tons per hr.

Located near the cooling bed are three annealing furnaces and 18 cooling pits for the processing of special steels. Also in the end of this building is a straightener for rounds, a 200-ton gag press, two pickling vats, conditioning beds, and roll turning facilities.

No. 1 merchant mill is a combination continuous, looping and cross-country layout offering a high degree of flexibility. Two pusher type, continuous, end-charge, end-discharge furnaces, fired with producer gas, serve to heat billets for this mill, with a fuel consumption of about 2,900,000 Btu per net ton rolled. The hearths of both furnaces are 11 ft 9 in. wide, with one having a length of 42 ft 8 in. and the other a length of 48 ft 8 in.

Leaving the furnace, heated billets first pass through a descaling unit where they are subjected to hydraulic sprays supplied with water at 400-600 psi pressure from pumps located at the blooming mill.

The first two stands of the mill are 18 in. roughing stands (No. 00 and No. 0), both driven through gears by a single 750-hp, 750-rpm, 6600-volt wound rotor induction motor. A hydraulically operated shear capable of cutting billets up to 4 in. x 4 in. follows the second rougher.

Billets next proceed through a continuous roughing train composed of six 14-in. stands, pass over a transfer and back through another 14-in. stand (No. 7), and then over another transfer and through another 14-in. mill stand (No. 8).

From this point, the steel may travel different paths according to the size of product. Leaving No. 8 stand, the larger sizes move straight down the mill table to stands No. 15 and 16, then over a 210 ft x 19 ft 3 in. cooling bed and on to a bar shear. Stands No. 15 and 16 are 14-in. units individually driven by 750-hp, 110-250 rpm, 230-volt d-c motors. When rolling in this manner, the two 18-in. roughing stands (No. 00 and 0) may be dummied for certain sizes. For small sizes, the bars leaving No. 8 stand are looped back for further reduction in a succession of 12-in. and 8-in. stands. Four 12-in. stands (originally three-high but now used only two-high) are placed side by side and driven as a unit through a single shaft. These are stands No. 9, 10, 11 and 12, and steel leaving No. 12 stand may proceed to either of two coiling reels capable of handling ⅜-1 in. rounds, or it may pass on to a 300 ft x 18 ft 7 in. cooling bed and a bar shear. If the section out of No. 12 stand requires still further reduction, it is looped over to No. 13 and 14, which are 8-in. stands, also located side by side and driven by belt from a line shaft running under the mill floor from the engine.

Intermediate sizes may follow still a different path from No. 8 stand, being taken back through No. 9 stand, then looped for finishing in No. 12 stand. With this reduction schedule, several stands in the 14-in. continuous train may be dummied.

All stands of this mill except No. 00, 0, 15 and 16 are driven through shafts, gearing and belts by a single 2500-hp, 32 x 56 x 60-in. 47-80 rpm steam engine equipped with a barometric condenser and operating on 160 psi steam pressure. Mill speeds are as follows:

Stand No.	Roll diameter, in.	Roll rpm	Speed, fpm
00	16.77	38.03	167
0	16.60	52.92	230
1	13.00	19.54	66.5
2	13.00	25.76	87.6
3	13.50	38.03	134.4
4	13.50	52.92	187.0
5	14.00	80.0	293.2
6	14.00	112.0	410.5
7	14.00	200.0	733.0
8	14.00	200.0	733.0
9	11.50	272.0	818.7
10	11.75	272.0	836.6
11	12.00	272.0	854.5
12	12.25	272.0	872.3
13	8.00	572.8	1199.7
14	9.00	572.8	1349.6
15	14.00	250.0	916.3
16	14.00	250.0	916.3

Products finished from the 14 in. stands include rounds 1-2⅛ in., squares ⅞-2 in., and flats 1½-6½ in. wide and ¼-¾ in. thick. From the 12-in. stand, finished sections include rounds $\frac{37}{64}$-1 in., squares $\frac{33}{64}$-1 in., hexagons $\frac{9}{16}$- ¾in., and flats $\frac{11}{16}$-1⅝ in. wide and $\frac{3}{16}$-¾ in. thick. The 8-in. stands turn out rounds ⅜-$\frac{37}{64}$ in., squares ⅜-½ in., and hexagons ⅜-½ in.

Billets entering the mill are either 4 x 4 in. or 5 x 5 in., and range 8-11 ft in length and 430-925 lb in weight. The average rolling rate for the entire mill is 12.4 tons per hr, but as much as 45 tons per hr can be rolled in the large sizes finished off the 14-in. mill. The main drives consume 34.6 kwhr and 600 lb of steam per ton rolled, while mill auxiliaries use another 15.5 kwhr per ton.

No. 2 merchant mill is an 18-in. and 12-in. cross

This 18 - 12-in. cross-country mill reduces 4-6 in. square billets to a wide range of round, square, flat and hexagon bars.

country mill consisting of two groups each containing five mill stands.

Heating facilities for this mill consists of three batch-type furnaces. Two of these are regenerative, with hearths 34 ft x 13 ft, while the third furnace is one-way fired and has a hearth 32 ft x 13 ft. All of these furnaces are fired with coke oven gas or natural gas, with a fuel consumption averaging about 3,500,000 Btu per ton of steel heated. Steel is handled into and out of the furnaces by a floor type turn-around charging machine.

The heated billets are placed on an approach table about 112 ft long, which carries them to the 18-in. mill. The first four stands of this mill are placed side by side and are driven as a unit through a 5.75:1 gear reduction set by an 1800-hp, 350-640-rpm, 500-volt, shunt wound d-c motor. This motor receives power from a motor-generator set consisting of two 750-kw, 250-volt, d-c generators connected in series, driven at 750 rpm by a 2000-hp, 6600 volt a-c motor.

The first three mill stands are 18-in. three-high units, while the fourth is an 18-in. two-high stand. Steel leaving the fourth stand travels over a table for a distance of about 88 ft to the two-high 18-in. finishing stand, which is a two-high unit driven through a 6.11:1 reduction gear set by a 600-hp, 400-800-rpm, 250-volt shunt wound d-c motor. Power for this motor is supplied by a 2000-kw motor-generator set which also supplies the two motors driving the 12 in. mill.

From the finisher, a runout table 128 ft long and containing a hot saw leads to a cooling bed 26 ft 6 in. x 75 ft. From the cooling bed, the steel passes over a table 85 ft long to a bar shear; piling cradle and scale.

For the smaller sizes, steel is taken from the second 18-in. stand and led over a table to the 12-in. mill, which consists of five 12-in. stands placed side by side. The first three of these stands are three-high, but are operated two-high. The first four stands are driven by a 1200-hp, 160-320 rpm, 250-volt shunt wound d-c motor, while the last stand of the mill is driven by a 500-hp, 175-350 rpm, 250-volt shunt wound d-c motor. Both of these motors receive power from a 1200-kw motor-generator set.

Following the 12-in. mill is a shuffle type cooling bed 13 ft 6 in. x 130 ft. A bar shear is located in the table following the cooling bed.

Conveniently located near the cooling beds of the 18-12-in. mill are a straightener for rounds up to 3½ in., and a 100-ton gag press that will handle bars and billets up to 6 x 6 in.

Speeds of the various stands in this mill are as follows:

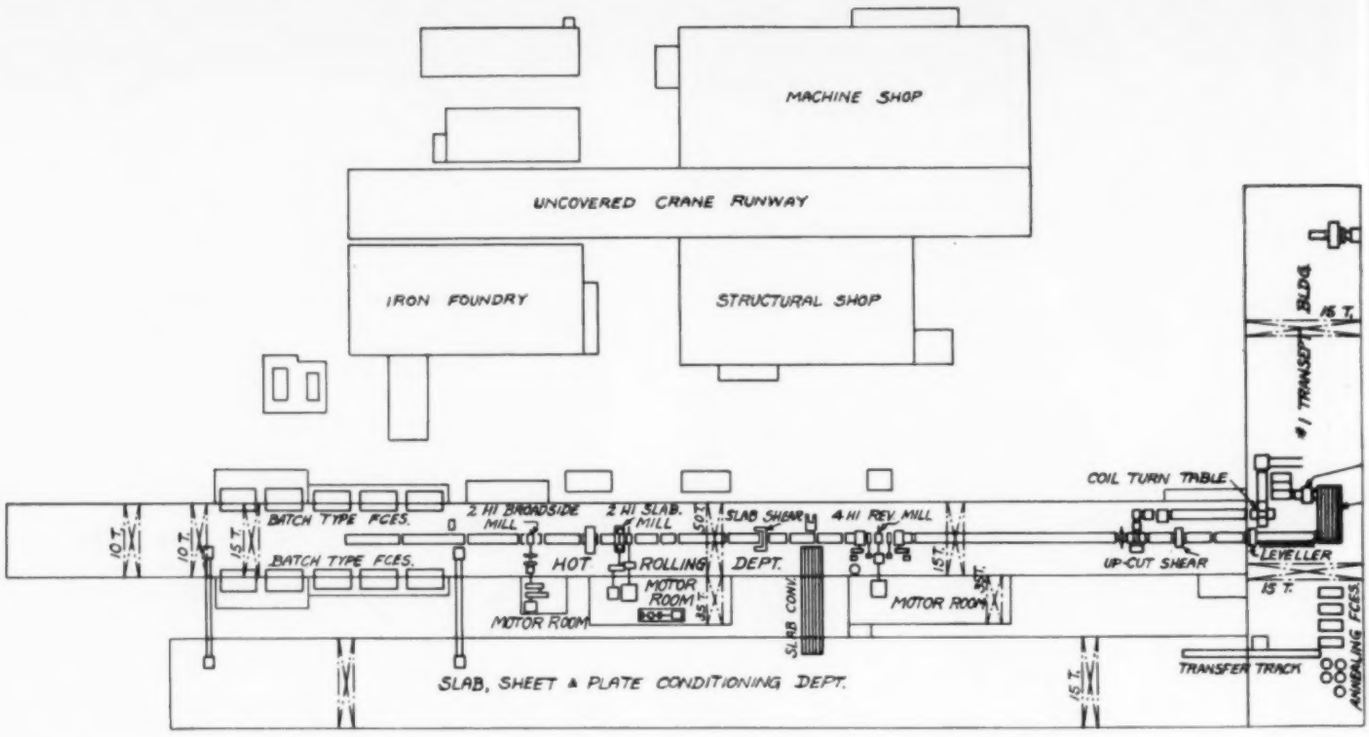
Stand No.	Roll diameter, in.	Roll rpm	Speed, fpm
1	17.5	60.8-111.3	278-510
2	17.5	60.8-111.3	278-510
3	17.5	60.8-111.3	278-510
4	17.5	60.8-111.3	278-510
5	17.625	65 -130	300-600
6	12.0	160 -320	502-1004
7	12.625	160 -320	528-1056
8	12.5	160 -320	523-1046
9	12.5	160 -320	523-1046
10	12.25	175 -350	561-1122

Billets charged to the mill are squares ranging 4 to 6 in. in cross section, 5-11 ft long and 270-1330 lb in weight. Products rolled cover a wide range of round, square, flat and hexagon bars. Sizes finished direct from the 18-in. mill include rounds $1\frac{17}{32}$-3¼ in.; squares $1\frac{3}{8}$-3¼ in.; flats $\frac{7}{8}$-$2\frac{3}{4}$ in. thick and 2-5 in. wide; and hexagons $1\frac{3}{8}$-$2\frac{7}{16}$ in. Such products may receive five passes in the first (rougher) stand, three in the second (pony rougher) stand, two in the third (strander) stand, and one in each of the fourth and fifth stands.

Sizes finished from the 12-in. mill include rounds $\frac{23}{32}$-$1\frac{33}{64}$ in.; squares ¾-1⅜ in.; flats ⅞ in. thick and 1¼-1¾ in. wide; and hexagons ¾-$1\frac{5}{16}$ in. These products may be given five passes in the 18-in. rougher, two passes in the 18-in. pony rougher, and one pass in each of the five 12-in. stands.

The rolling rate from the 18-12 in. mill varies widely, depending on the size being rolled. The average rate is 18.8 tons per hr, although production may reach as much as 35 tons per hr with the larger sizes finished on

This 100,000-lb drawbench is but one unit of the extensive facilities for finishing bars.



the 18-in. mill. Power consumption averages 69 kwhr per ton of product for the main drives and 15 kwhr per ton for mill auxiliaries.

To insure a high quality surface on the product from this mill, hydraulic descaling sprays are placed on the approach side of the 18-in. rougher, and on the delivery side of the third 12-in. stand. Water is supplied at 400-600 psi pressure from the hydraulic system at the blooming mill.

Three 18-in. roll lathes are placed in a roll shop adjacent to the mill building.

HEAT TREAT AND COLD DRAW

Heat treating, annealing and cold finishing facilities for bars and rods are centered at several locations. The original department, in a building conveniently located with respect to the merchant mills, contains four gas-fired conveyor type heat treating and quenching units, 13 gas-fired car-type furnaces, and two electric car-bottom furnaces; two bar picklers; three bar pointers; two double bar benches for cold drawing; eleven bar straightening machines; three bar straightening presses; three bar turning machines; one bar facing machine; two bar cracker shears; two bar cutting saws; and one bar chamfer and cut-off. In this department, treating capacity is 6500 tons per month, and cold draw capacity 3000 tons per month.

Another department, built during World War II for the Defense Plant Corp., is located near the plant, and contains nine gas-fired pit type furnaces, ten gas-fired car type furnaces, and 14 hood furnaces designed for

W. R. HOWELL
GENERAL SUPERINTENDENT

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ASSISTANT GENERAL SUPERINTENDENT

J. F. FERM
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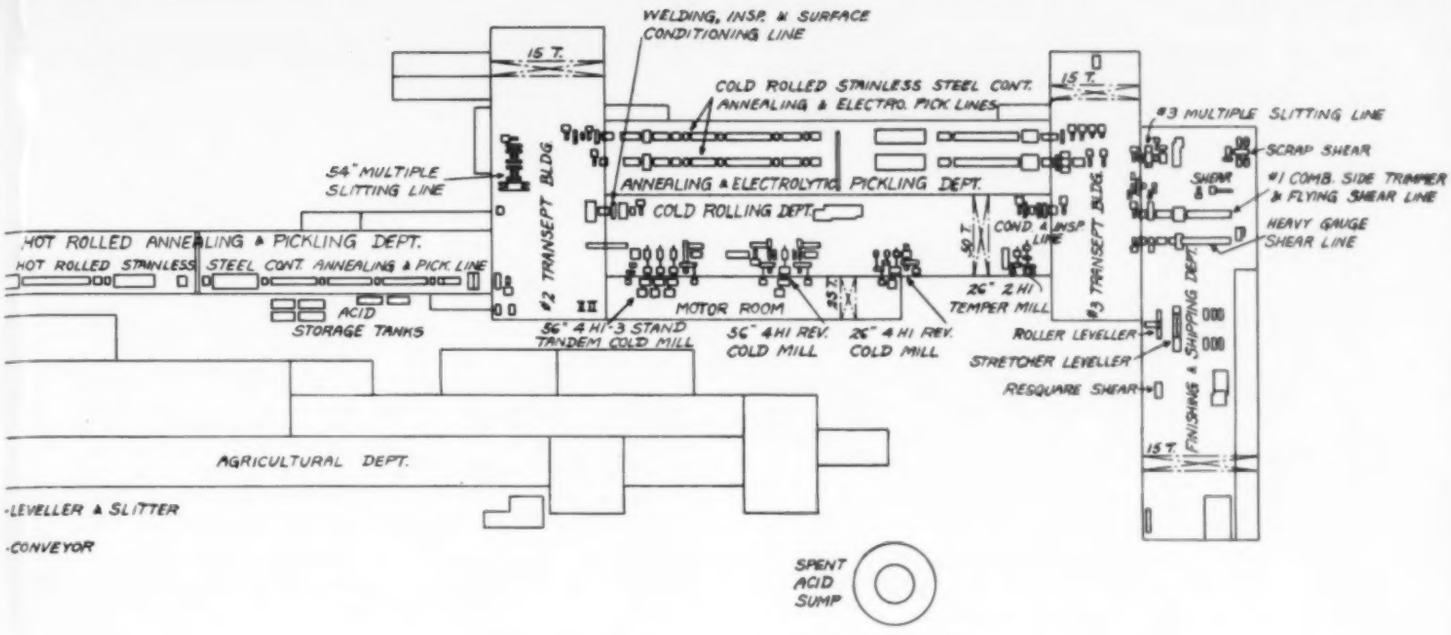


General layout of hot and cold strip mills.

protective gas annealing; six picklers for bars and coils; liming and baking facilities; seven draw benches; ten straightening machines; one gag straightener; nine centerless grinders; three cracker shears; three bar turning machines; and six hack saws. This plant has an annealing capacity of 8750 tons per month and a cold draw capacity of 4500 tons per month.

A third department, located at East Liverpool, Ohio, consists of 17 centerless grinders for bars ¼-3 in. in diameter. This unit has a capacity of 2500 tons per month.

STRIP MILL

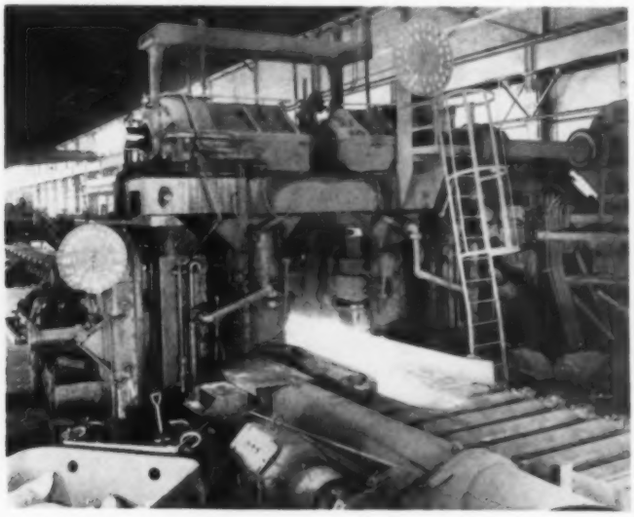
The most recent major addition to the facilities of the Midland plant is a strip mill designed primarily for the production of flat-rolled stainless and special alloy steels. Since a high degree of flexibility is essential, with only relatively low capacity, this installation does not follow the conventional layout of recent strip mills, but centers about a reversing hot strip mill.

To obtain the desired flexibility, the strip mill is designed to permit the rolling of ingots to slabs and the rolling of slabs to plate or to strip in all grades of steel. Also, some grades may be rolled direct from ingot to strip. At present, most of the slabs rolled into strip are broken down from ingots in this mill, but it is planned to increase the proportion of slabs coming from the blooming mill.

Whether slabs originate in the blooming mill or are produced in the strip department, they usually pass into the conditioning department for surface processing by scarfing or grinding. From this point, slabs are moved into the mill building by transfer buggies, from which they are moved into the heating furnaces by two overhead charging cranes. Heating facilities consist of

This two-high stand, driven by a 1500-hp motor, is the first unit in the hot strip mill recently built at Midland.

Vertical edging rolls and a two-high slabber form the principal roughing unit of the hot strip mill.



ten batch type furnaces arranged in two rows of five furnaces each.

The furnaces are 38 ft long overall, with 34 ft hearths. Six of the furnaces are 18 ft wide and have three long-flame combination gas and oil burners on each end, while the other four are 20 ft wide and have four burners in each end. The narrower furnaces are constructed with sprung arch roofs, while suspended arches are used on the wider units.

Coke oven gas is the principal fuel, with some natural gas used for heating stainless steels. Fuel oil is also available as stand-by. Fuel input averages about 58,500,000 Btu per hr per furnace, or 6,550,000 Btu per ton for the double heating. The usual heating cycle for ingots is five to eight hours, although certain special steels require up to 24 hr of heating. The average production of each furnace is 9 tons per hr.

All of the furnaces are equipped with two points of automatic temperature control. A metallic tubular recuperator is installed on one furnace, raising combustion air temperature to about 650 F. Waste gases enter the recuperator at 1500 F and exit at about 1100 F.

Combustion air for the ten furnaces is supplied by four 10,000-cfm fans and four 5333-cfm fans.

Slabs heated to rolling temperatures are taken from the furnaces by the overhead charging cranes and deposited upon the mill approach table, which is 170 ft long. The first unit of the mill train is a two-high 32-in. x 72-in. stand driven through gearing of 20.47 ratio by a 1500-hp, 2300-volt, 514-rpm, three phase wound induction motor, giving a roll speed of 24.8 rpm or 216 fpm.

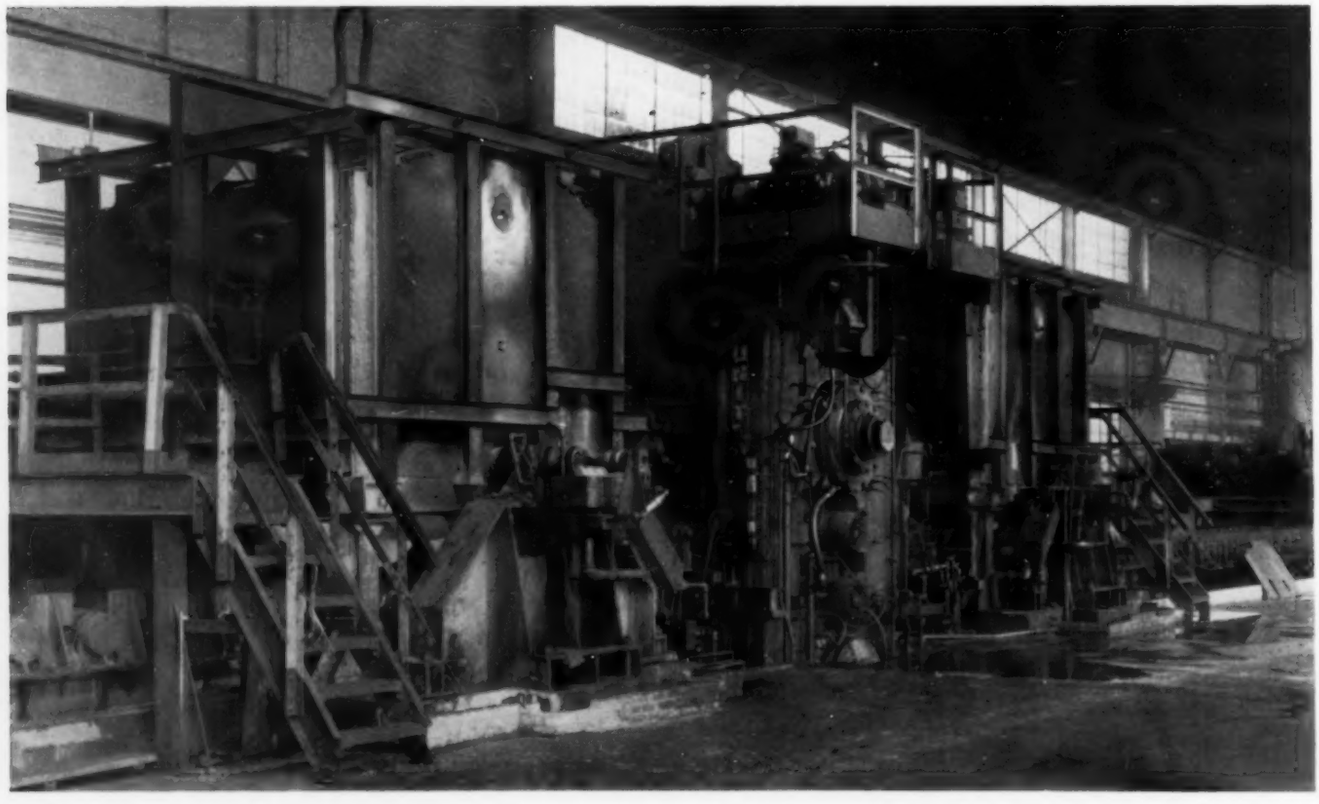
On each side of this stand is a hydraulically operated turntable, by means of which the slab may be revolved 90 degrees for cross-rolling of certain special products. This stand is not used for broadsiding in its usual sense of widening the slab. A pneumatically operated slab pusher on each side of this stand aids in entering the slab between the rolls. The next unit, 98 ft away, is an edging stand with vertical rolls 28 in. in diameter x 30 in. long, and this is followed at a distance of 7 ft by a two-high, 31½ in. x 69-in. reversing slabbing mill. The edger is driven at 51.2-122.6 rpm through gearing of 2.93:1 ratio by a 1500-hp, 150-360-rpm, 600 volt d-c compensated shunt wound motor, while the slabber is driven direct by a 5000-hp, 60-120 rpm, 750-volt d-c compensated shunt wound motor.

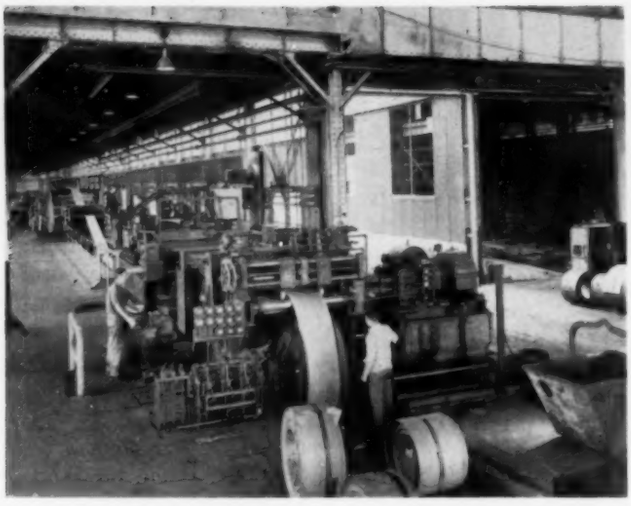
Power for the edger drive is provided by a 1250-kw, 600-volt d-c generator driven at 720 rpm by a 1750-hp, 11,000 volt a-c motor, while the slabber receives power from two 2000-kw, 750-volt d-c generators driven at 514 rpm by a 5000-hp, 11,000-volt motor provided with flywheel and slip regulator. The edger and the slabber work together as a reversing unit, with a top mill speed of 985 fpm.

Next in line is a guillotine slab shear, 64 in. wide, for cropping slabs and cutting to desired lengths. From this point, slabs may proceed on to the reversing mill if direct rolling is desired, or they may be carried over a 20-ft wide slab conveyor into the adjacent conditioning building for scarfing or grinding before being transferred back to the heating furnaces previously mentioned.

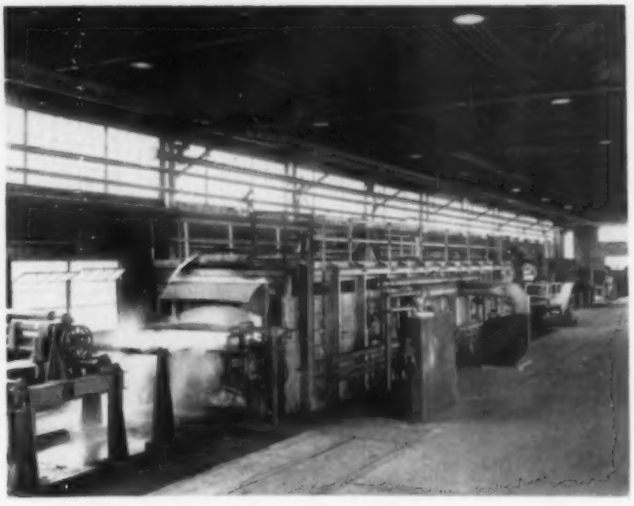
The reversing hot mill, which is located 265 ft beyond the slabbing unit, is a four-high, 27-in. and 49-in. x 66-in. stand, driven direct by a 5000-hp, 70-170-rpm,

Hot strip is finished in this four-high reversing hot mill. A hot-coiling furnace containing a reel is placed at each side of this stand.





Entry end of No. 1 continuous annealing and pickling line. Product from the hot strip mill passes through this line before going to the cold mills.



The normalizing furnace in the pickling line is used only on grades of steel requiring this treatment. With other grades, the strip passes over the top of the furnace.

800-volt d-c compensated shunt wound motor which derives its power from a motor-generator set composed of two 2000-kw, 800-volt d-c generators driven at 514 rpm by a 5600-hp, 11,000-volt motor. The mill has a maximum speed of 1200 fpm.

On each side of the reversing mill is a hot-coiling furnace containing a slotted reel driven by a 150-hp, 250-volt d-c motor. These reel motors operate under adjustable voltage control, and receive power from a six-generator set which, with another similar set, supplies the mill tables, pinch rolls and slab shear. The reel revolves continuously unless it is stopped to receive the end of a strip for coiling. Strip leaving the mill is deflected upward by a guide in the table, and the reel receives the end of the strip and starts coiling automatically. A set of pinch rolls also serves to guide the strip on each side of the mill between the stand and the coiling furnaces. The coiler furnaces are gas-fired to temperatures of 1200-2100 F, usually about 2000 F.

Composition bearings are used on the roll necks of the broadside and slabbing stands, with bronze bearings on the edger. The four-high reversing stand uses roller bearings on the work rolls and oil-flooded bearings on the back-up rolls. Babbitted bearings are installed in all pinion stands, and roller bearings in the gear sets.

All mill screws are operated by 250-volt d-c mill type motors, with a double drive connected by a magnetic clutch on the four-high stand.

Throughout the rolling process, steel surface is kept free of scale by the action of hydraulic descaling sprays which are located at the broadside, slabbing and reversing stands. Water is supplied from two centrifugal pumps rated at 400 gpm, 1200 psi. Spray valves are operated by air pilot valves actuated by solenoids. Steam jets for descaling are also provided at the reversing mill.

Radiation pyrometers are installed at the slabbing stand, at the reversing stand and at the final coiler, so that temperatures of the steel may be controlled as dictated by metallurgical requirements.

Lubrication of the hot strip mill is effected by means of ten circulating oil systems, 13 splash oil systems, five pump-operated grease systems, and 13 hand-operated grease systems. Approximately 199 bearings are served with extreme pressure oils, and consume about 550 gal of oil per month. Grease is supplied by the systems to 735 bearings.

Leaving the reversing mill, the hot-rolled strip moves over the mill table for a distance of 264 ft to an up-coiler, or if desired, on to a 60-in. up-cut shear, a roller leveler and a cooling bed. A slitter and another roller leveler for plate material is also provided at the end of the cooling conveyor. The coiler will form coils 30 in. inside diameter, up to 56 in. outside diameter, up to 50 in. wide, and up to 27,000 lb in weight.

Coils removed from the hot strip coiler are up-ended, weighed, and conveyed into the adjacent transept building. This building also contains annealing facilities made up of two rectangular portable annealing covers and two cylindrical covers. The furnaces burn natural gas, and prepared atmosphere is provided by a 2500 cu ft per hr gas-conditioning unit.

As indicated in the foregoing description, rolling may proceed in several ways. Ingots may be reduced to slabs of 4-9 in. in the slabbing stand and taken directly to the four-high reversing mill for finishing into strip. Or the slabs may be transferred from the mill to the conditioning department, and subsequently reheated for re-rolling. With some types of steel or with very large ingots, two reheatings may be necessary. It is possible to rough ingots into slabs at the same time a strip is being rolled on the four-high mill.

Slabs used in this mill may range 13-50 in. wide, 3-12 in. thick, 4-15 ft long, and 1000-16,000 lb in weight. A slab thickness of about 4 in. is normal practice, with reduction carried down to about ¾ in. thickness in 5-11 passes in the slabber for entry into the four-high unit. In this stand, strip may be rolled down to No. 14 gage in widths up to 50 in., and down to No. 18 gage in widths up to 38 in. Average thickness of the product rolled is 0.125 in. This gage can be produced from the ¾ in. break-down in 5-7 passes.

The mill is nominally rated at 21,700 tons of product per month. Average rolling rates are 90 tons per hr for slabbing, and 35 tons per hr for strip rolling, although hourly rates of 140 and 65 tons per hr have been reached

General view of cold mill department.

for the two operations, respectively. Approximately 25 per cent of the product from the hot strip mill goes into full-finished product, while 75 per cent is hot finished. About 30 per cent goes out in coil form and 70 per cent in flat product.

Connecting into the transept building which receives the hot mill product is a building containing a 570-ft continuous annealing and pickling line. At the entrance of the line is an uncoiler and leveler that uncoils, flattens and feeds out the hot-rolled strip. A 60-in. up-cut hydraulic shear is next in line, to square strip ends before welding. Butt or lap welding of the strip to form a continuous band is performed by a 600-amp, d-c welding machine mounted on a 13 ft x 22 ft welding car. A 70-ft looping pit follows the welding car.

At the entry end of the annealing furnace, which is the next unit in the line, is a tension wiper to provide back tension on the strip. The furnace itself, fired with coke oven or natural gas, is 52 ft 8 in. long x 10 ft 6 in. wide, and is designed to maintain temperatures up to 2200 F for the annealing various grades of stainless steel. The furnace is by-passed when processing the straight chromium grades. A water dip tank follows the furnace to cool the strip before entry into the pickling tanks.

Four pickling tanks, each 7 ft 2 in. wide x 48 ft 8 in. long x 3 ft 4¾ in. deep, are installed in tandem. Each tank contains 5990 gal of pickling solution, and is of steel plate construction, lined with rubber and acid resistant brick. Tank covers are also of steel plate construction, lined with rubber, and are vented to the outdoors by individual fans.

Next in line is a high-pressure water spray, followed by a hot water rinse tank, a dryer, pinch rolls, a 60-in. up-cut shear, tension rolls and a coiler.

When pickling stainless steel, the first three tanks of this line are filled with a 15 per cent solution of muriatic acid, automatically maintained at 180 F by injected steam. The fourth tank contains about 12 per cent of nitric acid and 3 per cent of hydrofluoric acid, at a maximum of 170 F. Straight sulphuric acid in a 15 per cent solution is used when pickling carbon steel. Strip speed through this line ranges 3-36 fpm, and the unit has a capacity of 2000 tons per month.

Cold reduction facilities consist of three rolling units. The first of these is a three-stand tandem train of four-high 16½ in. and 53 in. x 56 in. stands spaced on 13 ft centers and each driven by a 1500-hp, 250-650 rpm, 600-volt d-c shunt motor. All of these drives operate through gear reduction sets with ratios and speeds as follows:

Stand	Motor rpm	Gear ratio	Roll rpm	Strip speed, fpm
No. 1	250-650	4.4	57-147	245-635
No. 2	250-650	3.57	70-182	300-785
No. 3	250-650	3.18	79-204	340-880

Work and back-up rolls, pinions and reduction gears all run in roller bearings. Mill screws are operated by two 50-hp mill-type motors which can be operated separately or, through a magnetic clutch, as a unit.

At the entry end of the tandem mill is a traversing uncoiler with hydraulic coil lift and wedge-type expanding mandrel. Back tension is maintained by the uncoiler, which is connected to a 100-kw drag generator. At the exit end of the mill is a coiler, also with expanding mandrel, and hydraulic coil lift. A belt-wrapper serves to start the strip around the mandrel. The coiler is driven by a 600-hp motor.

Power for the main drives and reel drives of the tandem mill comes from a motor-generator set consisting of three 1250-kw 600-volt generators, one 500-kw 600-volt generator, and one 100-kw 250-volt generator, all driven at 720 rpm by a 6000-hp, 11,000-volt synchronous motor.

This tandem cold mill has a capacity of 4000 tons per month of stainless steel strip, and rolls widths ranging 18 - 50 in.

The tandem mill has a capacity of 4000 tons per month of stainless sheet and strip, and produces cold rolled and intermediate coils in widths 18-50 in. and in gages down to 0.018 in.

Another cold reduction unit is a single stand, four-high, 16½ in. and 53 in. x 56-in. reversing mill. This mill is driven through a 2.53:1 reduction gear set by a 2000-hp, 200-500-rpm, 600-volt d-c motor, and attains strip speeds up to 850 fpm. Roller bearings are used on all roll necks, pinions and reduction gears. Two 50-hp mill motors operate the screwdown.

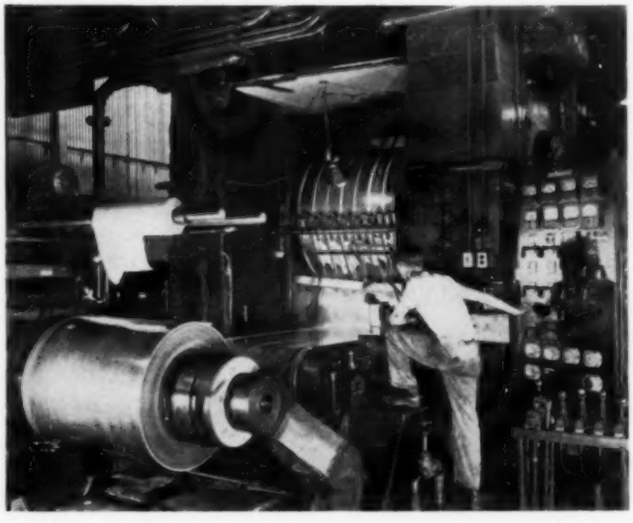
Strip is handled at the entry and exit sides of the reversing mill by equipment duplicating that on the tandem mill.

The reversing mill receives power from a motor-generator set composed of one 1600-kw and one 500-kw generator at 600 volts, and one 100-kw and one 50-kw generator at 250 volts, all driven by a 3000-hp, 11,000-volt, 514-rpm synchronous motor.

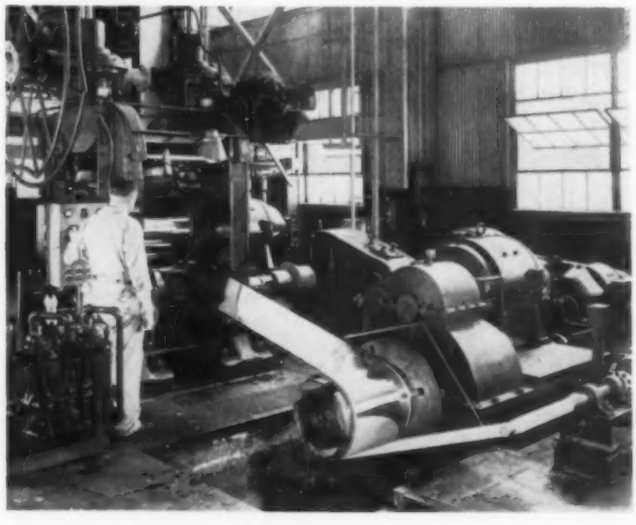
This mill is used to cold reduce hot rolled and intermediate strip to specified gages, and to temper roll strip for required physical properties and finish. It handles gages ranging 0.018-0.187 in., in widths of 18-50 in. and has a capacity of 1600 tons per month.

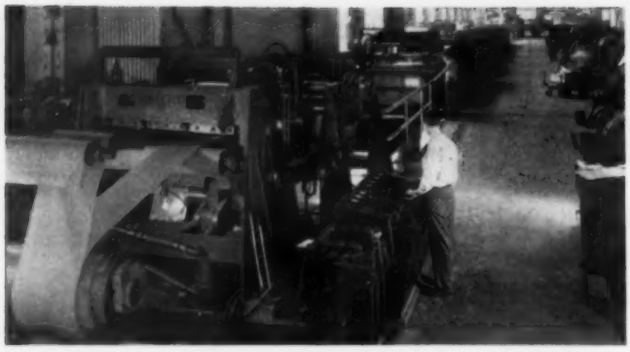
The third cold reduction unit is a 12½ in. and 33 in. x 26-in. four-high reversing mill driven by an 800-hp, 400-800-rpm, 600-volt d-c motor. Driven through a gear set of 3.14 reduction ratio, the mill attains a maximum delivery speed of 835 fpm. Strip handling is similar to that on the two cold mills just described. Mill screws are driven by two 10-hp mill type motors. Oil film bearings are applied to the backup roll necks of this mill, with roller bearings on work rolls, pinions and reduction gears.

Four-high cold reversing mills reduce hot rolled and intermediate strip to specified gages, and also temper roll for required properties.



Temper rolling to impart the desired physical properties and finish may also be done on this two-high 25 in. x 26-in. mill.





Two additional continuous annealing and pickling lines are used for intermediate processing of stainless steel between cold reductions.

A 700-kw motor-generator set supplies power to the mill drive, and a 400-kw set to the reel motors.

The function of this mill is the same as that of the 56-in. reversing mill. Product will range 8-23 in. in width, and 0.008-0.187 in. in thickness. Capacity is stated as 800 tons per month.

Total reduction in cold rolling is usually about 70 per cent of the hot rolled gage. In such cases, a reduction of about 50 per cent is made before the intermediate annealing, with the remaining reduction following.

A skin pass mill is also installed, consisting of a single stand 25-in. x 26-in. unit, driven through gearing by a 125-hp, 400-1200-rpm 230-volt d-c motor. Strip speed ranges up to 240 fpm.

Facilities for intermediate annealing and cleaning of the strip during the cold reduction process consist of two continuous annealing and pickling lines, generally similar to the line previously described. Strip paid off the uncoilers passes through a leveler, a 60-in. cropping shear, a 400-amp d-c lap welding machine, and a looping pit. The next unit in line is 10-ft x 52-ft gas-fired annealing furnace, designed to operate at temperatures of 1300-2150 F. When the line is being used only for pickling, the strip passes up over the top of the furnace.

Leaving the furnace, the strip passes on through a water dip tank before entering the pickling tanks. Each line contains three pickling tanks, the first and last 7 ft 2 in. wide x 26 ft 8 in. long x 2 ft 8 in. deep, with the middle tank being 7 ft 2 in. x 48 ft 8 in. x 3 ft 4¾ in. These tanks are of similar construction and are similarly vented as those on the line previously described.

In both of these intermediate lines, electrolytic equipment is provided on the first and third pickling tanks, which normally use a 4-6 per cent solution of nitric acid for pickling stainless steel. The center tank contains approximately 12 per cent nitric acid and 3 per cent hydrofluoric acid, and is by-passed when running straight chromium types of stainless steel. Power for the electrolytic pickling comes from two motor-generator sets rated at 7500 amp at 8 volts, 3750 amp at 16 volts.

The remainder of each line consists of a water spray rinse, a hot water rinse tank, a dryer, pinch rolls, a 60-in. up-cut shear, tension rolls and a coiler.

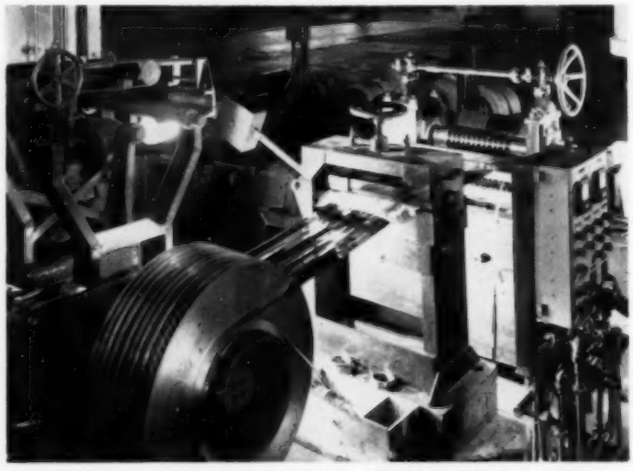
One of these lines is designed for both heavy and light gages, and operates at strip speeds of 5-75 fpm. The other, for the lighter gages, runs at 10-150 fpm. This line has two reels at each end and can be used as a two-strand line on narrow widths.

Completing the finishing equipment are four shear lines, three slitter lines, two resquaring shears, a roller leveler, a stretcher leveler and an oiling machine.

Lubrication of the cold mills and finishing equipment is carried out by 53 oil systems and 10 grease systems. Of the oil systems, which serve approximately 380 bearings with an oil make-up of 52 gal per month, 20 are circulating systems and 33 are splash systems. Two of the 10 grease systems are automatic pump systems, and eight systems are hand operated. Approximately 94 bearings are served by the grease systems.

AGRICULTURAL DEPARTMENT

Agricultural parts, for which the company enjoys a long-standing reputation, forms an important product of the Midland plant, and include heat treated plow and harrow discs, and soft center and solid sheared shapes for plow shares, moldboards and other parts of agricultural implements.



This light multiple strand slitter is cutting 20½ in. x 0.015 in. stainless steel into 1¾ in. widths.

In the process of manufacturing discs, steel plate is first blanked out into circles ranging 8-32 in. in diameter in three 400-600-ton presses. The discs then go by conveyor to four 75-200-ton stamping presses where center holes are punched out. The discs are then loaded on conveyors and travel to either of two production lines, No. 1 for large discs, No. 2 for smaller sizes.

In No. 1 line the discs pass through a forming furnace where they are heated to about 1300 F and then rolled to give a bevel edge. Next, notches may be sheared around the circumference if notched discs are desired. The next step entails heating in the hammer furnace, shaping in two 2500-lb steam hammers, and reheating in a quench furnace. The discs then go to quenching presses, and are conveyed through a scrubber and a tempering furnace, and are finally cooled and inspected.

No. 2 line is similar, but does not have the hammer furnace or the steam hammers.

Grinders, polishers and a paint line complete the process. Disc production ranges 1200-3000 tons per month.

Discs are generally made from either of two grades of steel:

	Carbon	Alloy
C	0.75-0.85	0.55-0.65
Mn	0.85-1.00	0.60-0.80
P	0.04 max	0.04 max
S	0.04 max	0.04 max
Si	.....	0.20-0.30
Cr	.....	1.15-1.45
Mo	.....	0.30-0.40

The plow division contains slitting, leveling and shearing equipment to form the various specified shapes from solid or clad plate. If the run should be big enough to justify the manufacture of dies, a 500-ton hydraulic press may also be used. This department processes about 800 tons per month.

The soft center plate is made up of the following grades:

	Outside layer	Inside layer
C	0.85-1.10	0.08-0.13
Mn	0.40-0.60	0.30-0.50
P	0.04 max	0.04 max
S	0.04 max	0.05 max
Si	0.15-0.30	.....

SERVICES

Electricity for the plant consists of both 25-cycle and 60-cycle power. The 25-cycle power, which represents about one-third of the total, is generated in the plant at 6600 volts and distributed by underground lead-sheathed cables to substations, main drive motors and motor-generator sets. Low voltage power is distributed at 220 volts a-c and 250 volts d-c. Power generating equipment includes one 2500-kw turbo-generator served by a 92-in. barometric condensers, one 4000-kw unit served by a 108-in. barometric condenser, one 10,000-kw unit equipped with low level jet condenser, and one 7500-kw unit equipped with a surface condenser. All of these units operate at 175 psi steam pressure, 1500 rpm, and generate three-phase 6600-volt, 25-cycle power.

About two-thirds of the power consumed comes from the utility company serving the district. This is 60-cycle power, transformed down to 11,000 volts for distribution by underground lead-sheathed cables through the plant. Lower voltages are distributed from several centers at 2200 volts a-c, 440 volts a-c, and 250 volts d-c.

Sixty-cycle power is used principally in the electric arc furnaces and in the new installations in the hot and cold strip mill group, while 25 cycle power supplies almost all the rest of the plant.

Power demand on the 60-cycle system totals about 48,000 kw maximum, 32,000 kw average at an average power factor of 97.5 per cent. Maximum demand on the plant-generated, 25-cycle power is 18,500 kw at 100 per cent power factor.

Steam for the turbo-generators and for the blast furnace blowing engines comes from two boiler houses located near the blast furnaces. One of these houses contains ten boilers, including two units rated at 75,000 lb per hr, 250 psi, 465 F, and fired with pulverized coal or coke oven gas, one unit rated at 1205 hp, 225 psi, 500 F and fired with pulverized coal, and seven units rated at 823 hp, 200 psi, 500 F. Of these seven boilers, two are fired with blast furnace gas, four with coal on underfeed stokers, and one with coke breeze on a chain grate stoker. The two 75,000-lb units are a recent addition. Each unit contains 8561 sq ft of boiler heating surface, 2087 sq ft of water wall surface, and 1795 sq ft of air heater surface. An efficiency of 85 per cent or higher is attained by these units. All of the boilers in this house are equipped with combustion control, steam flowmeters, and the usual regulators and gages.

The second boiler house at the blast furnace contains 14 boilers, all fired with blast furnace gas. Four boilers are rated at 608 hp, 200 psi, 500 F, while ten which serve as standby and are normally idle, are rated at 350 hp, 170 psi, 500 F.

Another boiler house, located near the blooming mill, supplies steam for the engines in the blooming mill, bar mill and No. 1 merchant mill. This house contains ten 603-hp boilers which operate at 200 psi, 500 F. Nine of these units burn coal on underfeed stokers, and one is equipped with a chain grate stoker for coke breeze.

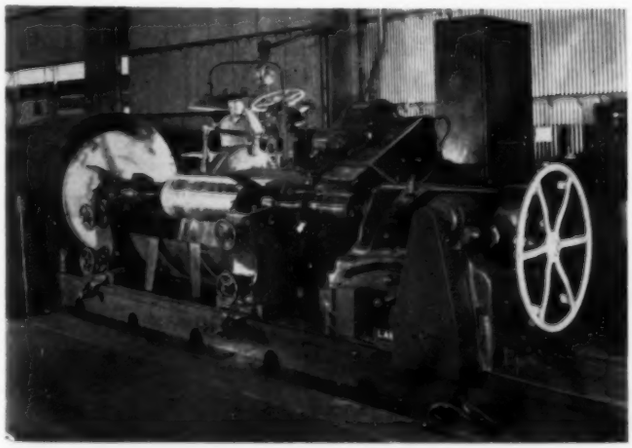
The Midland plant consumes approximately 66,000,000 gallons of water per day, which comes principally from the Ohio River. The river pump house contains two 22,900 gpm horizontal centrifugal pumps and three 11,800 gpm vertical centrifugal pumps. All are motor-driven, four from the 25-cycle power generated in the plant and one from the 60-cycle purchased power system. All five pumps deliver water at 150 ft head to a storage pond at plant yard level and to the plant condenser water system.

An auxiliary pump house, which pumps out of the storage pond to the plant water system, contains seven centrifugal pumps, three motor-driven rated at 7000 gpm, three turbine-driven rated at 7000 gpm, and one turbine-driven rated at 5500 gpm.

For boiler feed use, water is treated with lime and soda in a central filtration station of 2,500,000 gal per day capacity. Water from this plant is also used in locomotives and in hydraulic systems. A secondary phosphate treatment is used at each boilerhouse.

Approximately 1,000,000 gal per day of purchased city water is used for drinking and sanitary purposes, and for lubrication of composition bearings.

This roll grinder is used to keep strip mill rolls in good shape for turning out quality product.

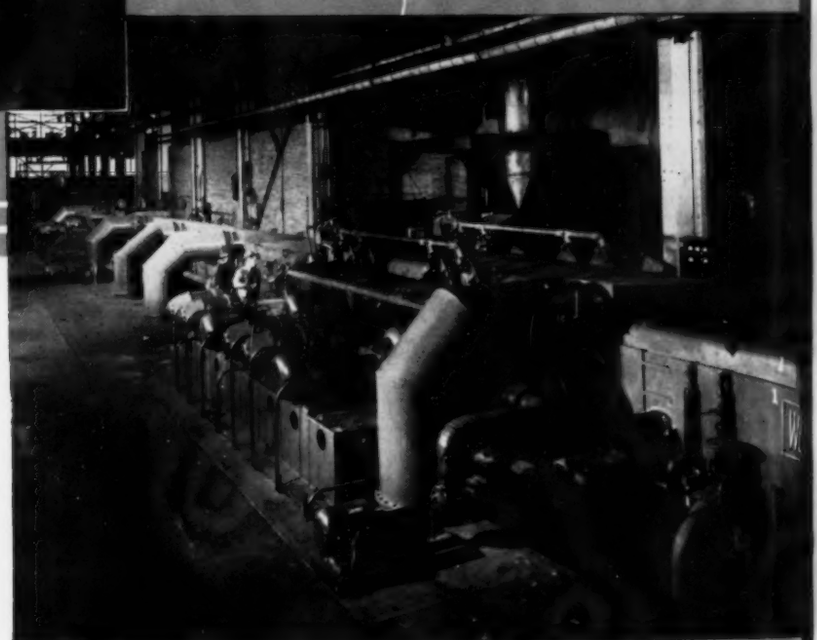


ENTRY END

The WEAN ENGINEERING Company, Inc.

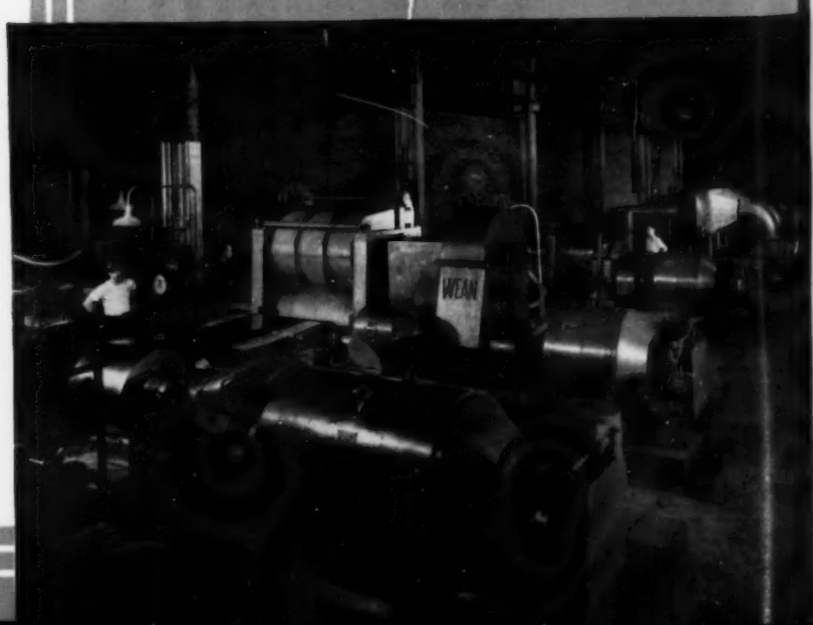
WARREN, OHIO

CLEANING SECTION



EXIT END

THE Wean "anodic cathodic" high speed electrolytic strip cleaning line represents the most advanced development in continuous strip cleaning. This line meets the most exacting requirements for subsequent coating operations.



SPECIALISTS IN SHEET, TIN & STRIP MILL EQUIPMENT

How Crucible Steel keeps cost-per-ton down...with TIMKEN® bearings

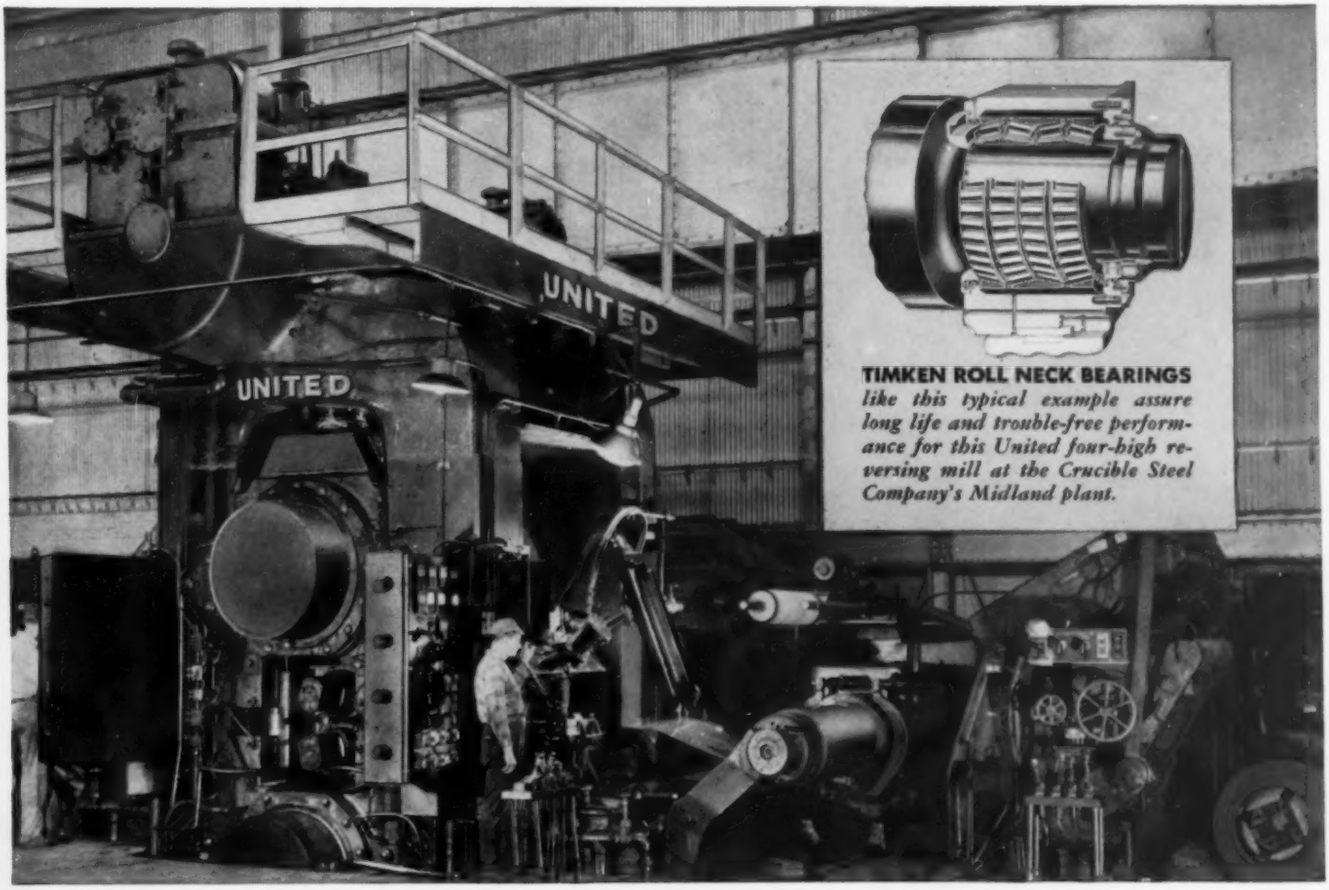
TO assure long life and trouble-free performance, Crucible Steel Co. chose this Timken®-equipped United 54″ four-high reversing mill for their Midland, Pa. plant. The work rolls, back-up rolls and screwdowns all turn on Timken tapered roller bearings. Timken roll neck bearings reduce friction, permit higher rolling speeds and eliminate roll neck wear.

Thanks to balanced proportion design, Timken bearings provide greater mill rigidity, permit larger roll necks than ever before possible with tapered roller bearings. Roll neck strength is increased 50 to 60%. Load ratings are increased up to 40%. Tonnage records in typical mills indicate that the long life of Timken roll neck bearings keeps bearing cost-per-ton-of-steel-rolled to a minimum.

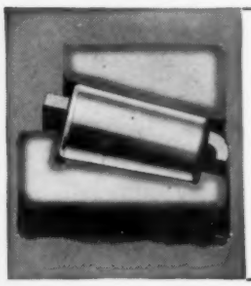
Timken bearings permit the use of simple grease lubrication. Complicated lubrication systems are unnecessary. Rolls can be changed easily and quickly. And since Timken bearings take both radial and thrust loads, no thrust bearings are necessary.

You can be assured of all these advantages in new or existing equipment by specifying Timken balanced proportion bearings for back-up and work rolls. For full information, consult our roll neck bearing specialists. Write The Timken Roller Bearing Company, Canton 6, Ohio. Canadian plant: St. Thomas, Ontario. Cable address: "TIMROSCO".

This symbol on a product means its bearings are the best.



TIMKEN ROLL NECK BEARINGS *like this typical example assure long life and trouble-free performance for this United four-high reversing mill at the Crucible Steel Company's Midland plant.*



GREATER LOAD AREA

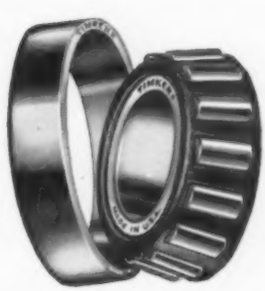
Because the load is carried on the *line* of contact between rollers and races, Timken bearings carry greater loads, hold shafts in line, wear longer.

The Timken Roller Bearing Company is the acknowledged leader in: 1. advanced design; 2. precision manufacturing; 3. rigid quality control; 4. special analysis steels.

TIMKEN

TRADE-MARK REG. U. S. PAT. OFF.

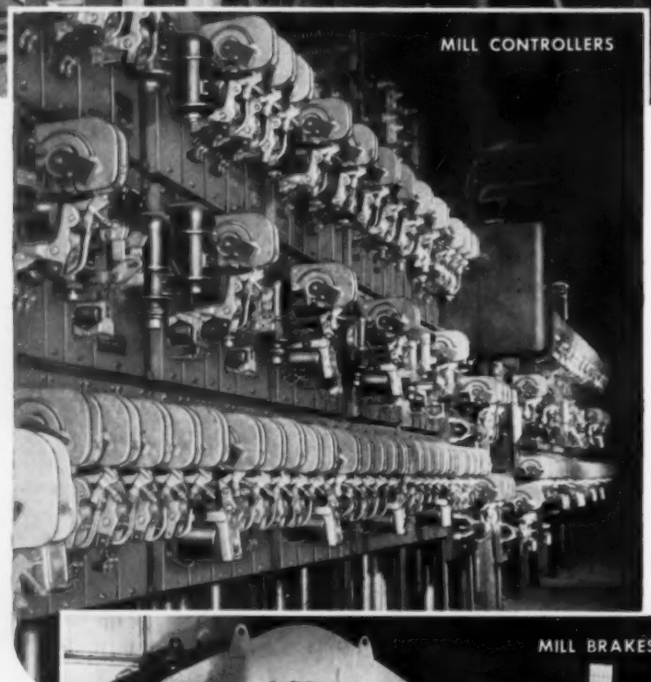
TAPERED ROLLER BEARINGS

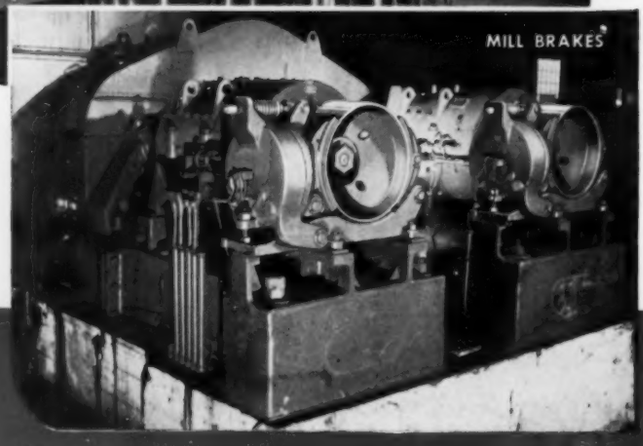


NOT JUST A BALL ○ NOT JUST A ROLLER ▭ THE TIMKEN TAPERED ROLLER ▭ BEARING TAKES RADIAL ◫ AND THRUST →◫← LOADS OR ANY COMBINATION ✳

EC&M MOTOR CONTROL

HELPS KEEP STEEL PRODUCTION UP!





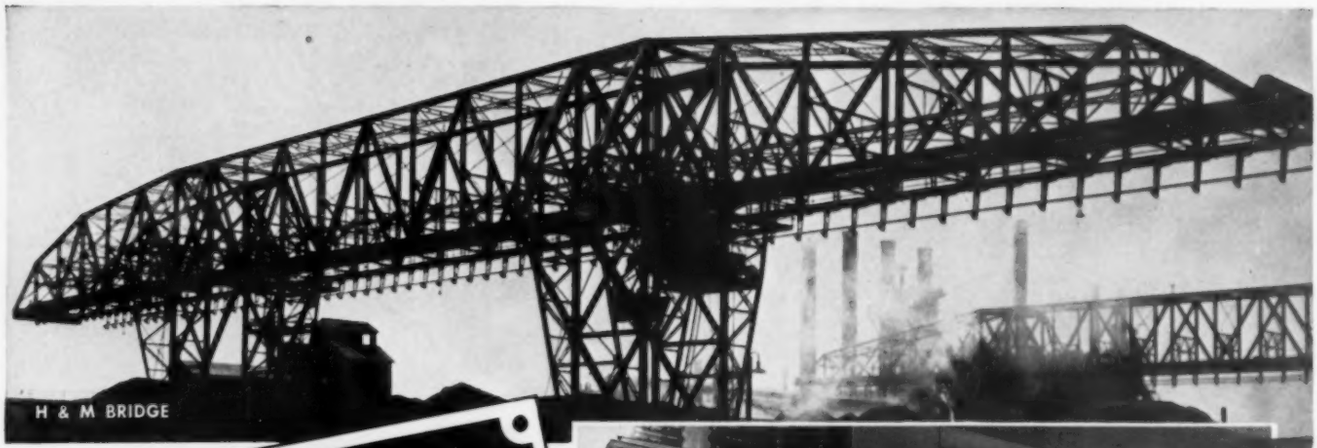
Short-throw EC&M Bulletin 1190 Master Switches are easy on operators—reduce fatique. The 7-inch diameter cams minimize handle-throw from "off" to "full-speed" in each direction. Note, too, how the narrow-width permits convenient grouping —easy to reach.

TIME-CURRENT Acceleration speeds Mill Auxiliaries—allows motors longer time to get under way when mills are cold—automatically shortens acceleration time as the mill warms up. Mills equipped with EC&M Bulletin 925 Controllers *continue to set production records.*

Quick responding brakes—only the armature moves in EC&M Bulletin 1004 Type WB Brakes. Thick, tough brake blocks give long wear. These *long-life* brakes are available for both AC and DC motors.

O. H. STOCKYARD MAGNET

The EC&M ALL-WELDED Lifting Magnet provides a better proportion and use of coil space, giving FULL LOADS of light scrap, as shown above.



H & M BRIDGE

EC&M TIME-CURRENT CONTROL

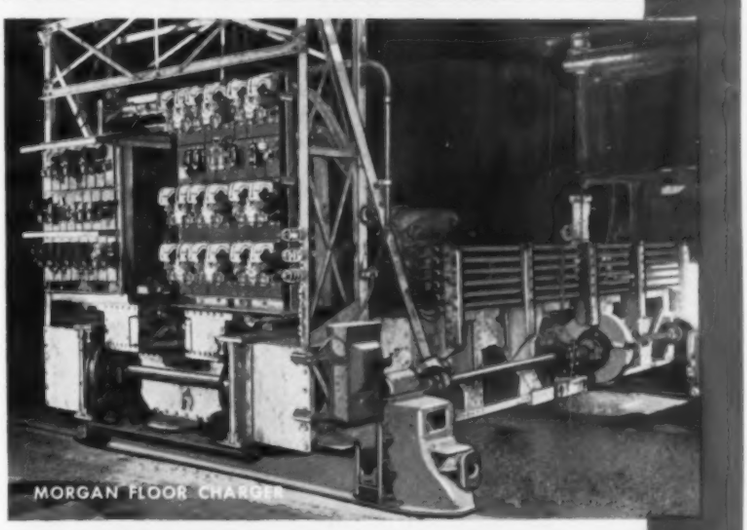
ALLIANCE OVERHEAD CHARGER

HAS OUTSTANDING ADVANTAGES FOR CRANES, CHARGERS, BRIDGES

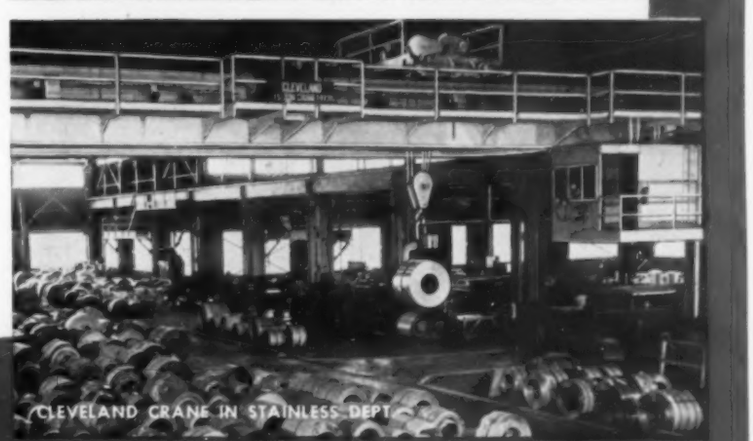
There is no performance equal to that provided by an EC&M Bulletin 921 Crane Controller. Contactors are fast-operating — acceleration is by the TIME-CURRENT method. This gives *load-responsive* characteristics which *operators use to advantage* in spotting a load, in taking the swing out of the hook, etc.

Parts easily accessible encourage good maintenance and here, again, EC&M excels. Front and rear contacts of LINE-ARC Contactors are replaceable on an average of less than 2 minutes. They can be loosened or tightened by a standard wrench and without dismantling any other contactor parts.

When buying cranes and similar machines, specify EC&M Control.



MORGAN FLOOR CHARGER



CLEVELAND CRANE IN STAINLESS DEPT.

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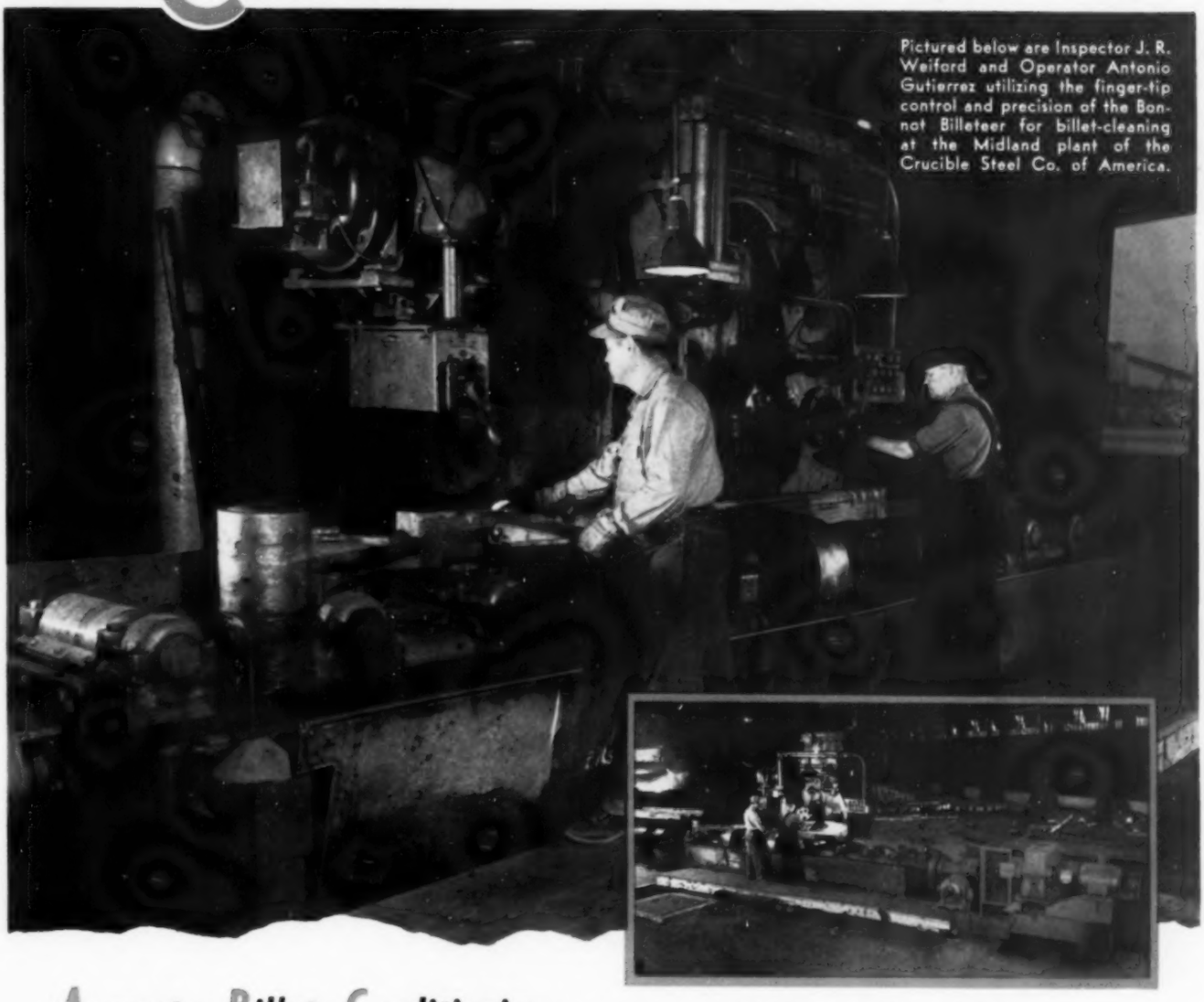
ACTION WITH BILLETEER AT CRUCIBLE STEEL OF AMERICA



Pictured below are Inspector J. R. Welford and Operator Antonio Gutierrez utilizing the finger-tip control and precision of the Bonnot Billeteer for billet-cleaning at the Midland plant of the Crucible Steel Co. of America.

Accurate Billet Conditioning is a prime requisite of steel production for war or peace, just as the A-B-C's are fundamental to general business. • With a *Bonnot Billeteer* you are assured of ACCURATE, FAST, SAFE, MODERN billet-cleaning that also REDUCES COSTS, CUTS MANPOWER TURNOVER and PROVIDES BETTER BILLETS. • As at Crucible Steel, Billeteer installations are Bonnot-engineered to meet individual plant needs. • For performance facts, write today!

Engineered For Improved Production

The Bonnot Co.
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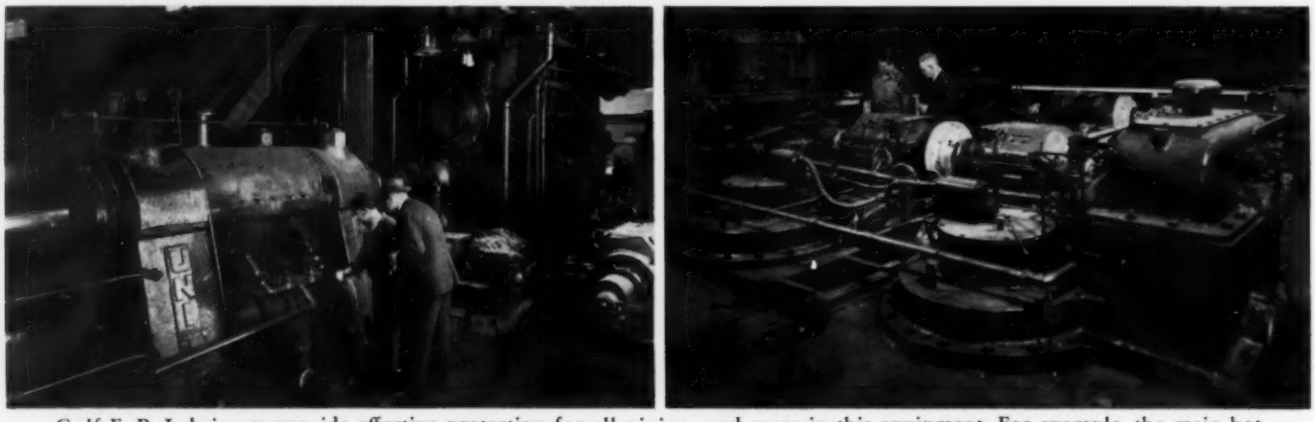
DUST PUG MILLS • SINTER PLANT PUG MILLS

GULF QUALITY LUBRICANTS
protect key equipment at Midland

13" and 49" x 66" 4-high reversing hot strip mill (left), and 16½" and 53" x 54" 3-stand tandem cold mill (right), of Crucible Steel Company of America at Midland, Pa. In these units back-up roll bearings are protected by Gulf I-C Oil and the roll balance hydraulic system is filled with Gulf Harmony Oil.



Gulf E. P. Lubricants provide effective protection for all pinions and gears in this equipment. For example, the main hot mill pinions (left), and the cold mill screw-down mechanisms (right) are protected by Gulf E. P. Lubricant 115.

In the new hot and cold rolled strip department of Crucible Steel's Midland Plant important units of equipment get safe, sure, efficient protection with Gulf Quality Oils and Greases.

For the Morgoil back-up roll bearing circulating systems, Gulf I-C Oil is used because of its outstanding resistance to sludging and excellent water separating characteristics.

For all pinion stands and reduction gear drives, Gulf E. P. Lubricants provide an extra margin of protection and insure low power consumption.

In all hydraulic systems, Gulf Harmony Oil protects against rust, foaming, and sludge.

There is a Gulf quality lubricant which will insure minimum wear for every gear and bearing in your plant—that will help you improve production and reduce maintenance costs! Write or phone today for a Gulf Lubrication Engineer.

GULF INDUSTRIAL LUBRICATION

GULF OIL CORPORATION · GULF REFINING COMPANY
GULF BUILDING, PITTSBURGH, PA.
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Located in principal cities and towns throughout
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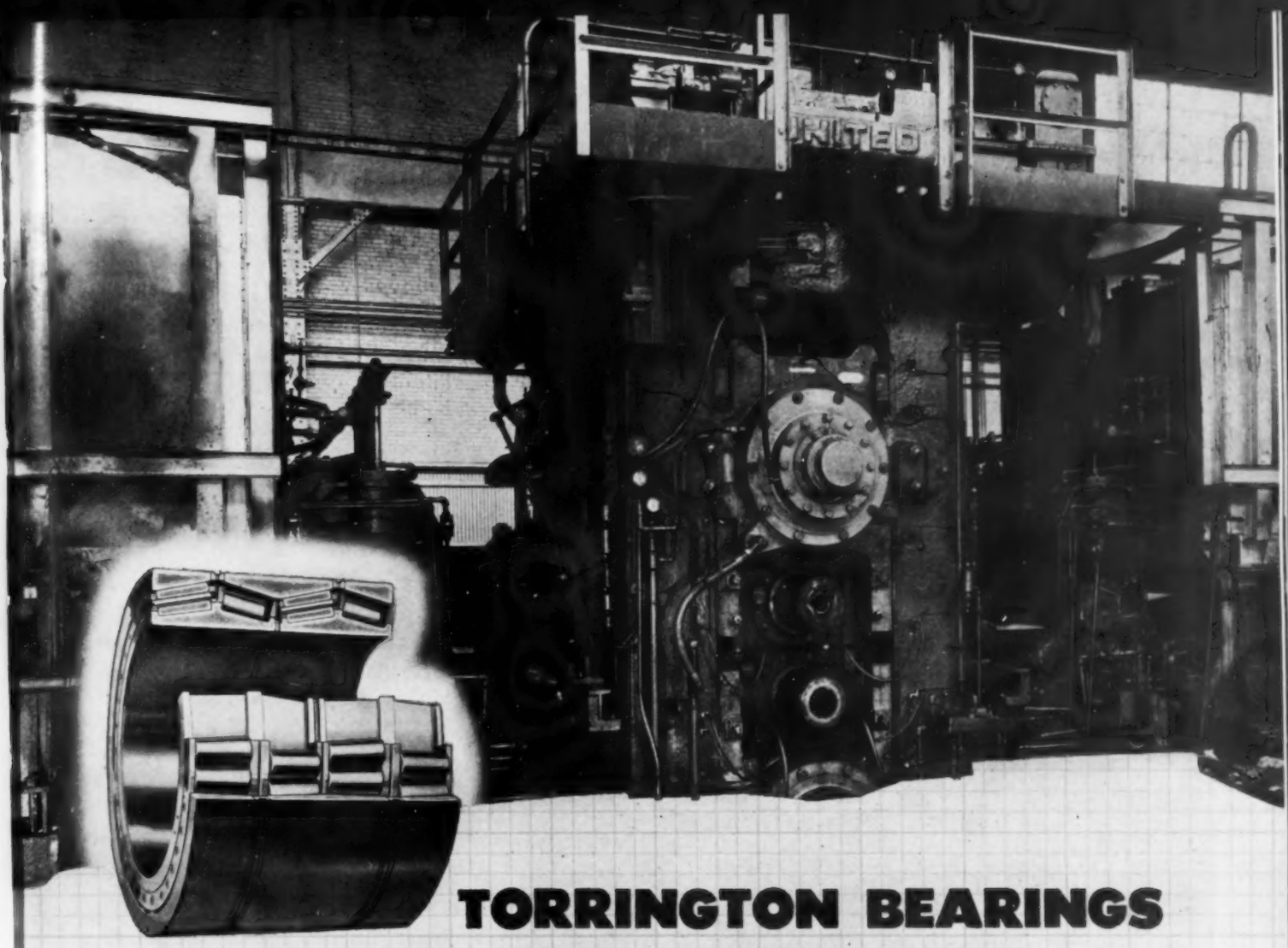

TORRINGTON BEARINGS

help roll Crucible's quality stainless steel

Heavy-duty Torrington Bearings contribute to the steady production of highest quality stainless steel in the new Crucible Midland mill. Work rolls of the special 66" 4-high reversing hot mill, as well as the work rolls and back-up rolls of the new 3-stand tandem cold mill, operate smoothly on Torrington Four-Row Tapered Roller Bearings.

Higher load capacity is available in Torrington Roll Neck Bearings with minimum cross-section to permit maximum roll neck diameters for greater strength.

Torrington engineers are always ready to help solve your friction problems. Call on us for bearing design, application or maintenance recommendations.

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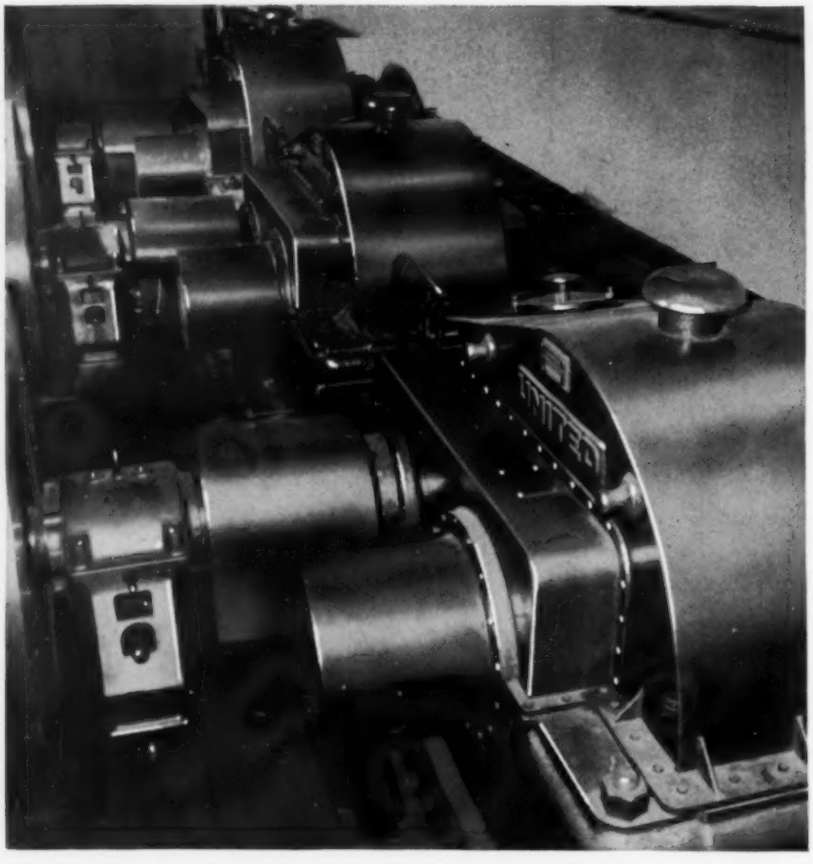
TORRINGTON *TAPERED ROLLER* **BEARINGS**

SPHERICAL ROLLER · TAPERED ROLLER · STRAIGHT ROLLER · NEEDLE · BALL · NEEDLE ROLLERS

SPECIAL PLANT for SPECIAL STEELS

Crucible's New Midland Plant - - the ultimate in sheet and strip mills for special purpose steels



Crucible's new plant is just about the last word in producing sheet and strip in stainless and similar special purpose steels.

For example, look at this 3-stand tandem 56-inch 4-high cold rolling mill built by United Engineering & Foundry Co. It's one of the few tandem cold rolling mills for stainless in the country. It cold reduces hot rolled and intermediate gage coils in widths from 18 to 50 inches. And its 1500 HP Gear Drives are equipped with SKF Bearings.

SKF Bearings are helping speed production of vital steel in equipment of every description. In every case, they are proving SKF's ability to help put the right bearing in the right place.

SKF INDUSTRIES, INC., PHILADELPHIA 32, PENNSYLVANIA—*the Pioneers of the Deep Groove Ball Bearing, Spherical Roller Bearing, Self-Aligning Ball Bearing.* 7156

OTHER MIDLAND EQUIPMENT WITH BEARINGS ENGINEERED BY SKF

Drives for Rod, Merchant and Billet Mills • Drives for Hot and Cold Mills • Shear Drives
Reel Drives • Bar Mill, Furnace Runout and Blooming Mill Feed Tables
Roll Necks of the Skin Pass Mill

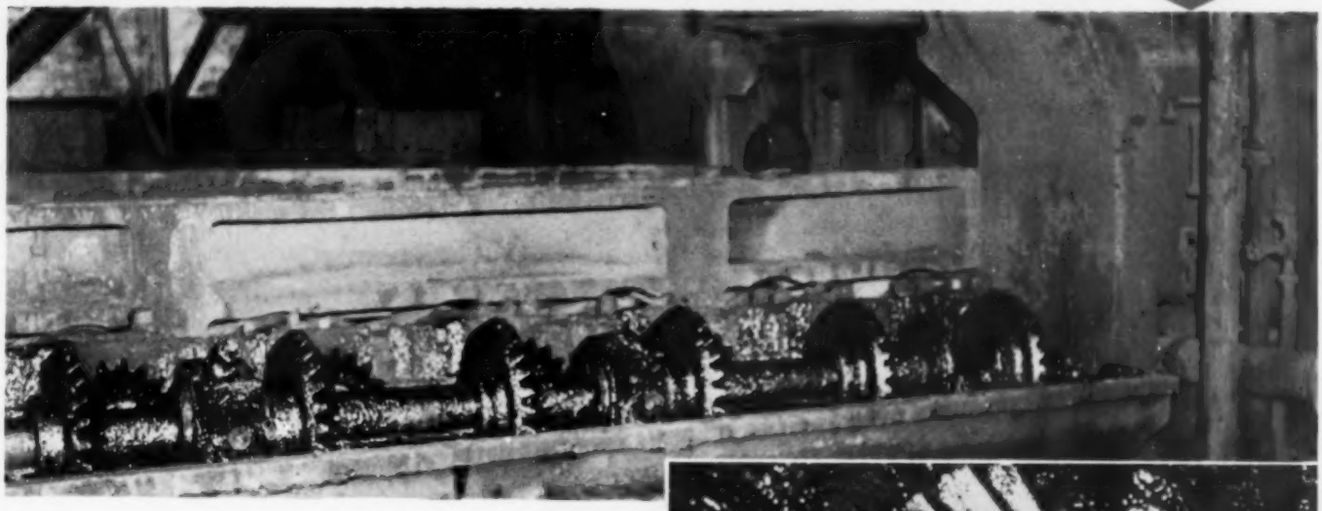
Above equipment built by Lewis Foundry & Machine Co., United Engineering & Foundry Co., L. W. Nash Co. and Fessler Machine Co.

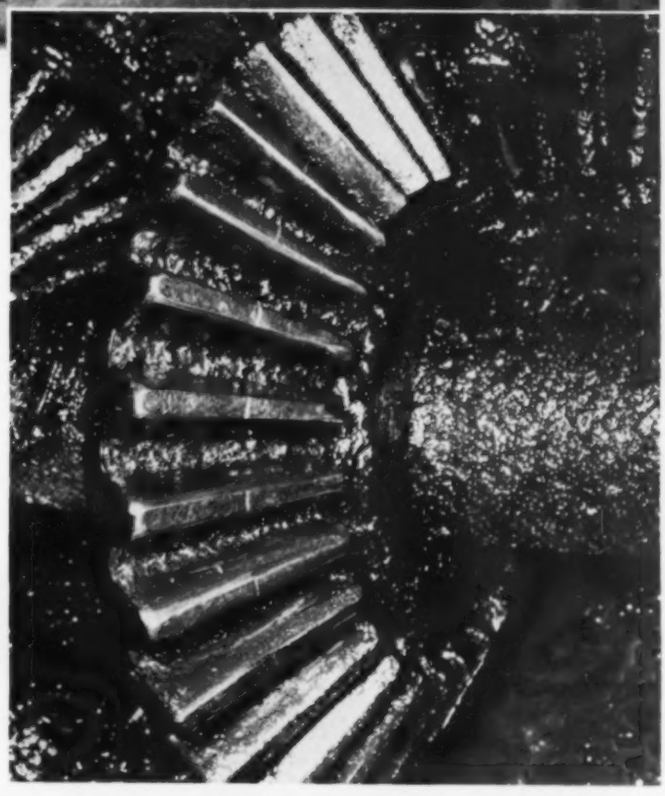
SKF
BALL AND ROLLER BEARINGS

8 REASONS WHY SKF IS PREFERRED BY ALL INDUSTRY

Integrity — Craftsmanship — Metallurgy — Tolerance Control
Surface Finish — Product Uniformity — Engineering Service — Field Service

"TOOL STEEL" BEVEL GEARS AT EXIT END OF 2-HIGH REVERSING MILL





AT CRUCIBLE STEEL'S
MIDLAND, PA., PLANT
IT'S

"TOOL STEEL" PROCESS

BEVEL GEARS

THAT ARE DELIVERING
OVER 5 TIMES THE LIFE OF ORDINARY GEARS

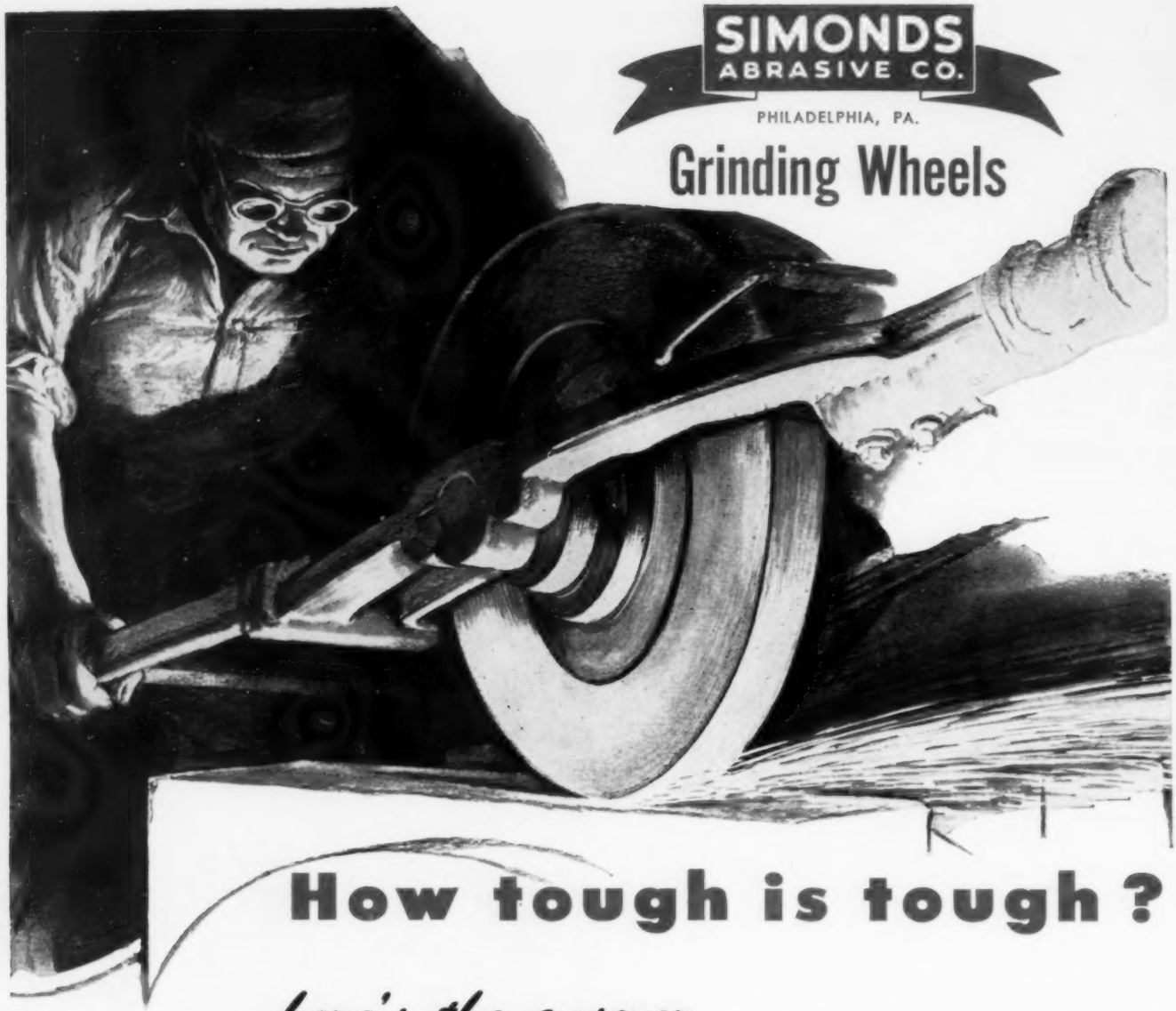
— they still show no appreciable wear!

This is just one of the hundreds of examples why "TOOL STEEL" can and does furnish you with a WRITTEN GUARANTEE to OUTLAST ANY OTHER PRODUCTS used in the same service!

"TOOL STEEL" PROCESS

The Standard of Quality
for GEARS • PINIONS • ROLLS • WHEELS *and other* HARDENED PRODUCTS

THE TOOL STEEL GEAR & PINION CO.
CINCINNATI 16, OHIO, U. S. A.



SIMONDS
ABRASIVE CO.
PHILADELPHIA, PA.

Grinding Wheels

How tough is tough?

here's the answer

in Crucible Steel Company's Midland Plant

Simonds Abrasive Company grinding wheels are tough . . . plenty tough to stand up to the stress and strain of high speed snagging . . . yet cut fast and give low cost per pound of metal removed.

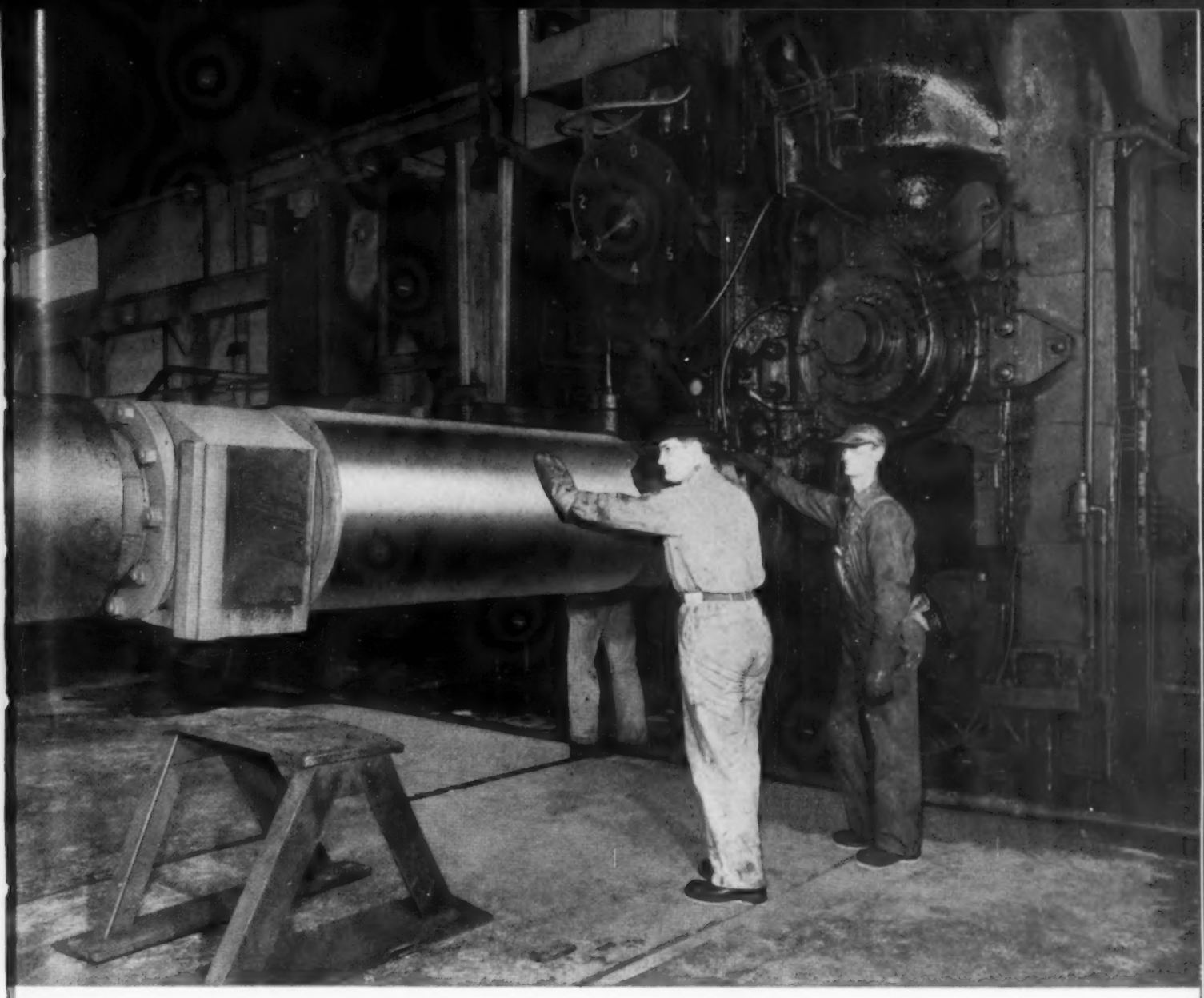
That's why Simonds Abrasive Co. Snagging wheels are standard for high efficiency at Crucible Steel . . . and why these and other kinds of Simonds Abrasive Wheels can give *you* top performance on everything from rough snagging to precision finishing.

Let's tell you more about our complete line of grinding wheels and abrasive grains, together with name of your nearest distributor. Write.

SIMONDS ABRASIVE COMPANY, PHILADELPHIA 37, PA., DISTRIBUTORS IN PRINCIPAL CITIES

GRINDING WHEEL INSTITUTE MEMBER

DIVISION OF SIMONDS SAW AND STEEL CO., FITCHBURG, MASS. OTHER SIMONDS COMPANIES: SIMONDS STEEL MILLS, LOCKPORT, N.Y., SIMONDS CANADA SAW CO., LTD., MONTREAL, QUE. AND SIMONDS CANADA ABRASIVE CO., LTD., ARVIDA, QUE



ready for service in the hot spot

MACK-HEMP STRIPED RED WABBLER ROLLS

Throughout the years, striped red wabbler rolls were used by leading producers under the hottest and hardest rolling-mill conditions. Then, in 1934, Mack-Hemp installed the first reversing hot strip mill with coil heating furnace. This pioneering experience with rolls for hot strip production resulted in the development of NIRONITE grain-type chilled rolls of special nickel alloy.

NIRONITE rolls are used in the 66-inch single stand reversing hot strip-sheet mill at Crucible Steel Company of America, Midland, Pennsylvania. The illustration shows a striped red wabbler work roll, 27" in diameter, being installed "ready for service in the hot spot" where a rolling speed of 1200 feet per minute is attained with strip temperatures up to 2100° F.

In rolling service like this, you'll find Mack-Hemp rolls with the striped red wabblers doing a productioneering job day after day. Why not drop a note to Mack-Hemp at Pittsburgh for details!

MACKINTOSH-HEMPHILL CO.

Makers of the Rolls with the Striped Red Wabblers

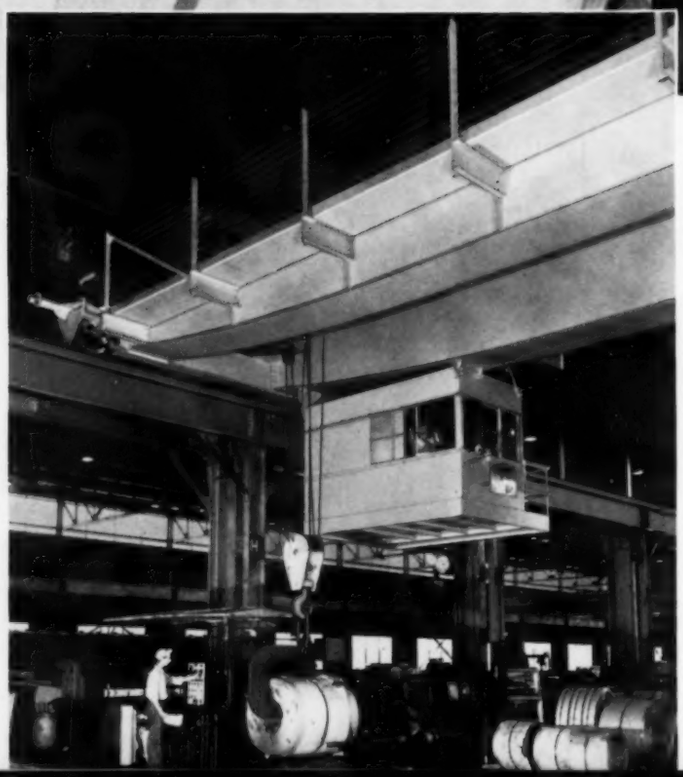
PITTSBURGH AND MIDLAND, PA.

MACKINTOSH-HEMPHILL PRODUCTS INCLUDE: ROLLS . . . STEEL AND SPECIAL ALLOY CASTINGS . . . COMPLETELY INTEGRATED STRIP MILLS . . . HEAVY DUTY ENGINE LATHES . . . THE NEW MACKINTOSH-ABRAMSEN STRAIGHTENERS . . . IMPROVED JOHNSTON PATENTED CORRUGATED CINDER POTS AND SLAG-HANDLING EQUIPMENT . . . SHAPE STRAIGHTENERS . . . END-THRUST BEARINGS . . . SHEARS . . . LEVELLERS.

CLEVELAND CRANES

MODERN ALL-WELDED STEEL MILL CRANES

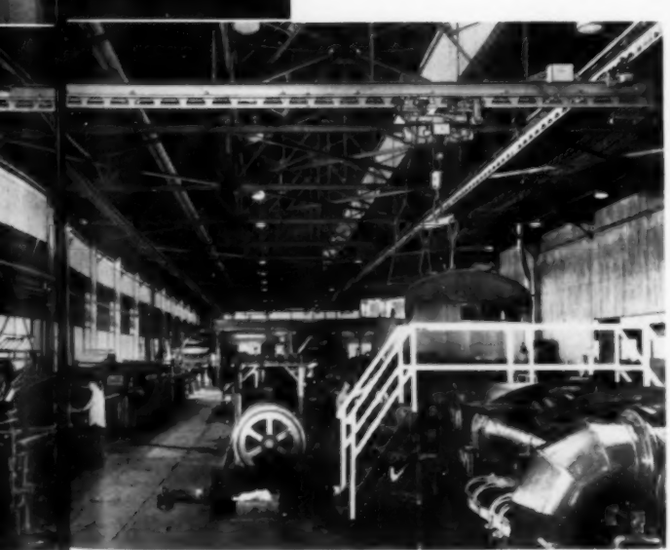
15 ton, 88'-0" span crane handling a nine ton coil of stainless steel at a hump shear.



MODERN CLEVELAND CRANES SERVE CRUCIBLE STEEL'S MODERN MIDLAND PLANT

15 ton, 88'-0" span crane serving No. 3 Transept Bldg. Like the other Clevelands, this crane is kept in nearly continuous motion, handling strip from rolling mill lines to storage, shears, shipping, etc.

15 ton, 112'-0" span Cleveland Crane in Finishing and Shipping Department, shown with sheet grab, placing stainless steel at stretcher leveler.



Cleveland Tramrail Cranes also serve some of Crucible Steel's lighter handling jobs. This view is of a 6000-lb., motor-driven crane over Nos. 2 and 3 Annealing and Pickling Lines. Heavy tank covers, rolls and many other items are handled with this crane.

A NUMBER of all-welded Cleveland Cranes are serving the new large mill section of Crucible Steel Company of America, Midland, Pa. Operating 24 hours a day, they handle large tonnages with dispatch.

Top performance with minimum maintenance is assured because the design and construction of Cleveland Cranes is based on experience with hundreds of mill cranes built over a period of more than 50 years.

THE CLEVELAND CRANE & ENGINEERING CO.

1131 EAST 289TH ST. • WICKLIFFE, OHIO

WITH 32 years of steel mill electrical construction experience, Dingle-Clark salutes Crucible Steel for its 50 years of fine steelmaking.

Our organization has served The Crucible Steel Company for many years. At the Midland plant, we installed the electrical construction on the cold mills and processing lines.

Dingle-Clark service has been built on these five fundamentals:

1. *Sound management and business policies,*
2. *Financial stability,*
3. *Technical responsibility,*
4. *Purchasing and expediting ability,*
5. *Experienced field construction supervision.*

In the emergency America now faces, our service to the steel industry will continue to operate on these fundamentals, to the same high standards of quality and dependability that have produced so many successful electrical construction projects in the past.

THE DINGLE CLARK COMPANY

Electrical Contractors

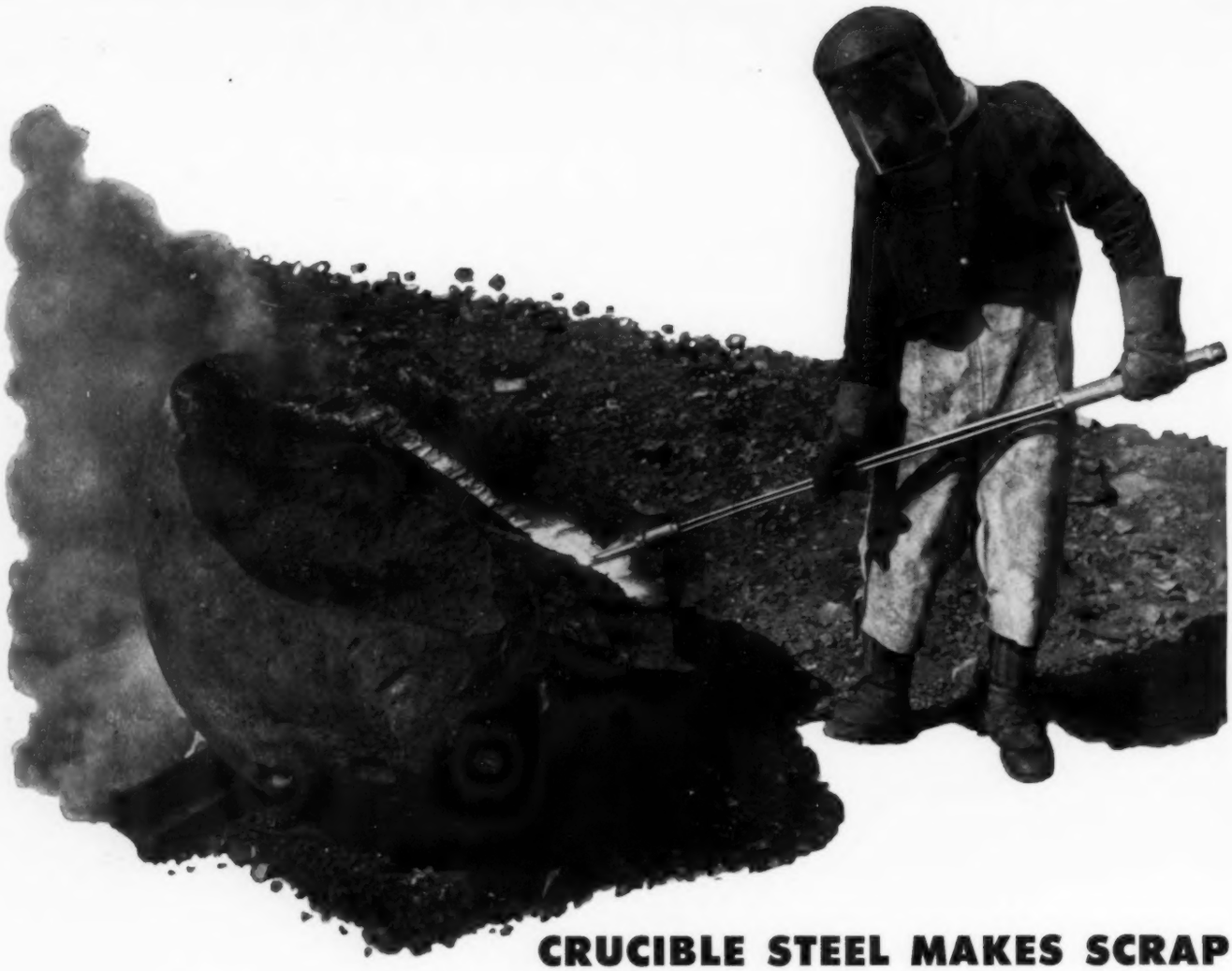
PITTSBURGH — *Main Office* CLEVELAND — PHILADELPHIA

UNITED ENGINEERING AND FOUNDRY COMPANY

Plants at Pittsburgh • Vandergrift • New Castle • Youngstown • Canton

Subsidiaries
Adamson United Company, Akron, Ohio
Lobdell United Company, Wilmington, Delaware
Stedman Foundry and Machine Co., Inc., Aurora, Indiana

Designers and Builders of Ferrous and Non-Ferrous Rolling Mills, Mill Rolls, Auxiliary Mill and Processing Equipment, Presses and other Heavy Machinery Manufacturers of Iron, Nodular Iron, and Steel Castings and Weldments.



CRUCIBLE STEEL MAKES SCRAP

pay big dividends

...HELP INCREASE PRODUCTION

To meet today's demand for increased production . . . at a profit—Crucible turned to its scrap yard, and found a gold mine. Here were tons of broken drop balls, skulls and buttons—tons of discarded high price steel just waiting for conversion to dividend producing income.

Knowing Airco's thorough familiarity with steel mill operation, Crucible called in an Airco Technical Sales Representative. He suggested reducing this old steel to charging box size with Airco's No. 6580 high-speed, high-pressure cutting torch. The outstanding cutting qualities of this 52", straight-head torch permitted easy and economical cutting of the heavy scrap . . . all jobs fell within its scope—regardless of size or shape.

Furthermore, to help facilitate this tremendous cutting operation, Airco's Technical man had an Airco oxygen supply trailer temporarily set-up at the scrap yard to provide the large quantities of high pressure Airco 99.5% pure oxygen needed for the job. Crucible was so well pleased with the results obtained, they purchased a number of Airco No. 6580 torches, and have put their scrap-cutting on a production basis.

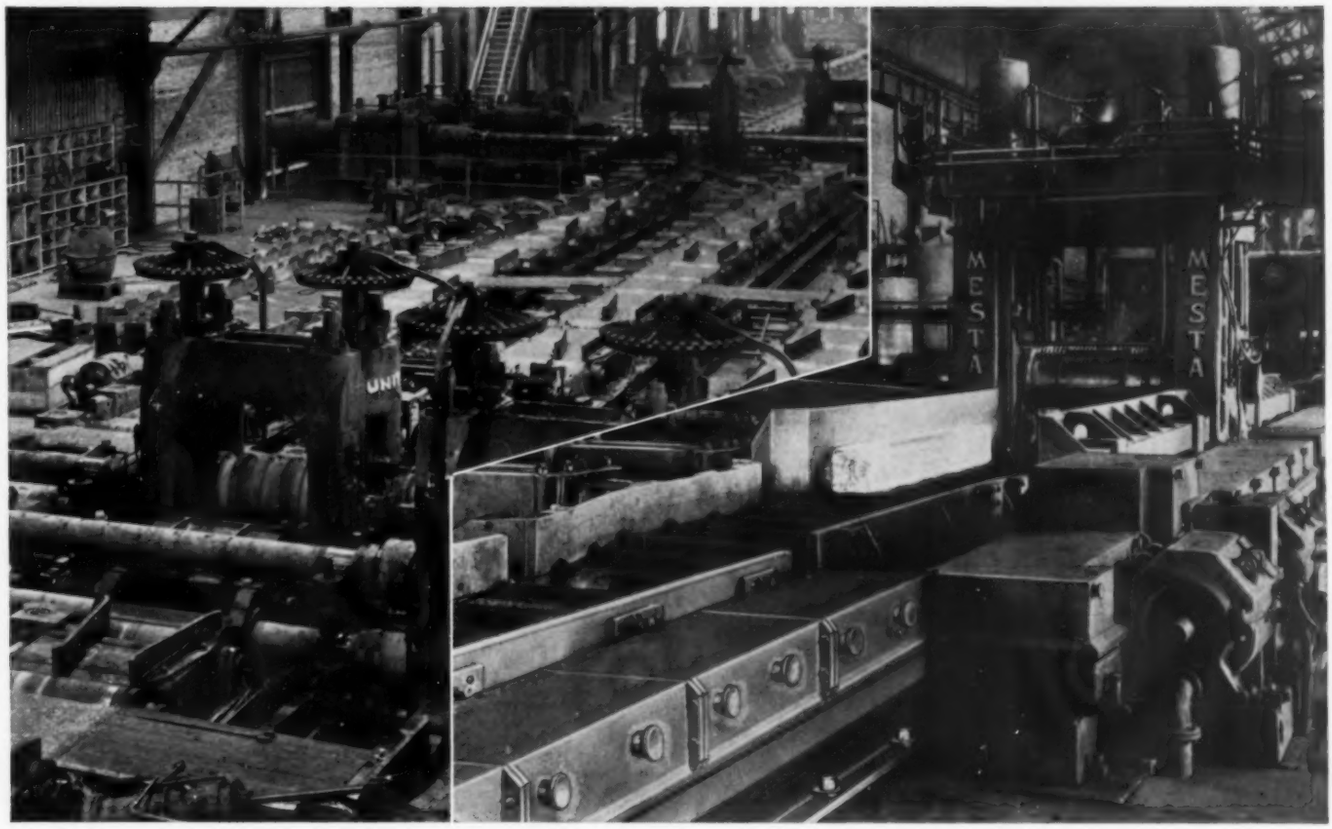
This is another example of the manner in which modern Airco oxyacetylene equipment is helping progressive operators slash time and costs. Ask to have an Airco Technical Sales Representative call to supply complete information. Write your nearest Airco office.

AIRCO AIR REDUCTION

Offices in Principal Cities

Headquarters for Oxygen, Acetylene and Other Gases...Calcium Carbide...Gas Cutting Machines...Gas Welding and Cutting Apparatus, and Supplies...Arc Welders, Electrodes and Accessories

HYATTS RATE HIGH—AT MIDLAND



MORE than 20 years ago Hyatt Roller Bearings were installed on the feed rollers, table rollers, lineshafts and drives of a 40″ Blooming Mill at Midland. Since then many more Hyatts have gone into service on Midland's cranes, ingot mold cars, charging box cars, motors and other mill tables.

Thus from this original installation, and the similarly successful Hyatt applications which followed, Crucible Steel has profited by satisfactory bearing performance for almost a generation.

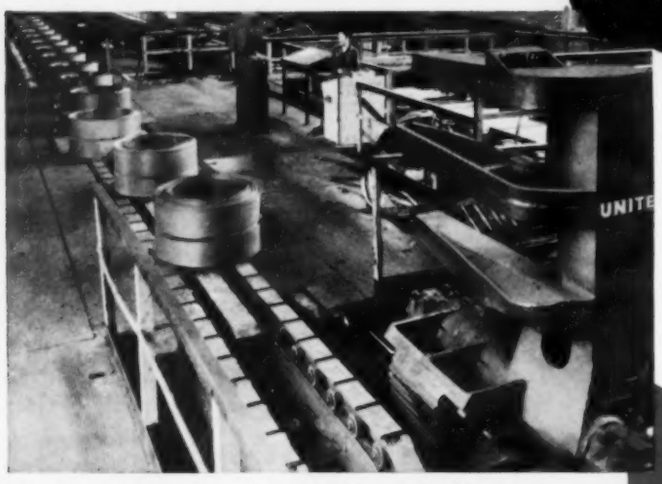
No wonder they, like the steel industry as a whole, continue to specify Hyatts for new equipment and use them so extensively for changeovers. Hyatt Bearings Division, General Motors Corporation, Harrison, N. J.

HYATT ROLLER BEARINGS

LINK-BELT...at work

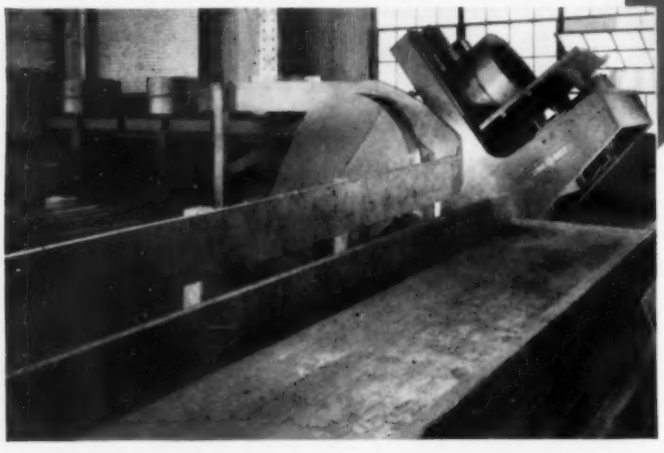
at CRUCIBLE STEEL COMPANY of AMERICA

MIDLAND, PA.



Hot strip coils weighing from 5,000 to 20,000 pounds each are transferred from the upcoiler and placed on end on this 118-foot long Link-Belt double strand Pallet Type Conveyor and carried through the weighing station to the end where they are automatically picked up by a Coil Lift and Turnaround Unit and transferred to the second Link-Belt Conveyor. The upender and conveyor are operated intermittently, the chain advancing by coil spaces.

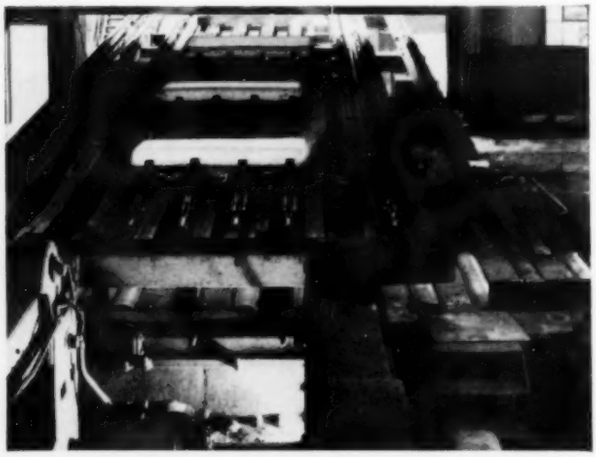
The Link-Belt hydraulically operated downtilter transfers the now-cooled coils from the end of the second conveyor and lays them on their side to roll along the inclined discharge ramp where they are picked up by overhead crane for transfer to shipping and storage areas. The space between the chains of the conveyors permits air to circulate for cooling the coils and also provides clearance for the arms of the loading, weighing, turning and unloading mechanisms. The design of the conveyors and the planned, gentle handling throughout eliminates costly damage due to scuffing of the edges of the coils.



This modern, special-steel sheet and strip mill with a processing capacity of 27,000 tons a month was designed throughout to achieve maximum versatility in the production of the company's variety of steels. Here, Link-Belt conveying equipment offers an excellent example of the conservation of man power, elimination of waste motion, mechanized handling that eliminates damage to the product, and low handling cost.

Link-Belt builds and installs the latest types of hot and cold coil conveying systems as well as other materials handling equipment. Link-Belt manufactures also a complete line of power transmission machinery for driving equipment and processing machines.

Link-Belt engineers will be glad to work with you on your conveying and power transmission problems. Ask our nearest office.



Link-Belt Chains and Sprockets are an important part of this transfer table. The slabs are 96" x 37" x 8", weigh 8050 pounds each, and most of them are between 1600° and 1800°. The table will hold ten slabs that ride on skids with pusher dogs in the chain transferring them at 60 feet a minute.

Installed by United Engineering & Foundry Company in conjunction with their 66-inch, 4-high reversing hot-finishing mill.

LINK-BELT

LINK-BELT COMPANY

Chicago 9, Indianapolis 6, Philadelphia 40, Cleveland 15, Pittsburgh 13, Atlanta, Dallas 1, Houston 1, Minneapolis 5, San Francisco 24, Los Angeles 33, Seattle 4, Toronto 8. Offices in Principal Cities. 12,172

THE SYMBOL OF QUALITY LINK-BELT LB

CONVEYING, PREPARATION and POWER TRANSMISSION MACHINERY

TREADWELL

LADLES

HOT METAL

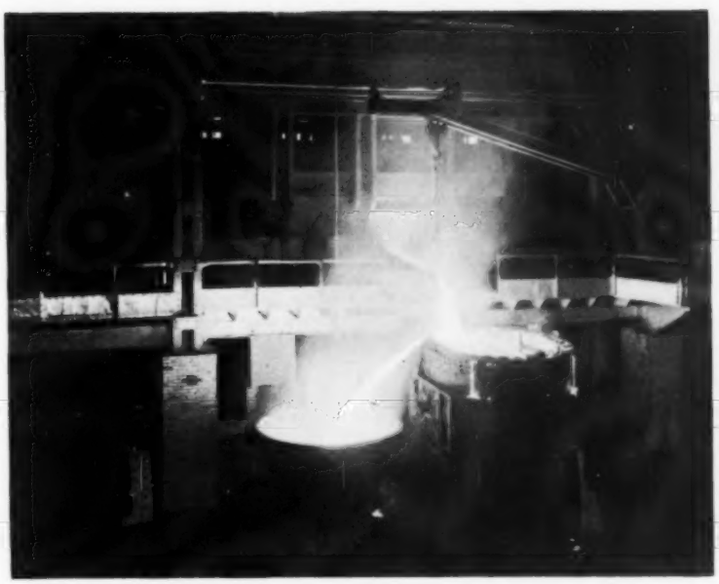
HOT METAL TRANSFER

BESSEMER

OPEN HEARTH

ELECTRIC FURNACE

FOUNDRY



WELDED and RIVETED for the STEEL COPPER BRASS ALUMINUM and ALLIED INDUSTRIES

140 Net Ton Open Hearth Ladles Built for Crucible Steel Co. of America, Midland, Pa.

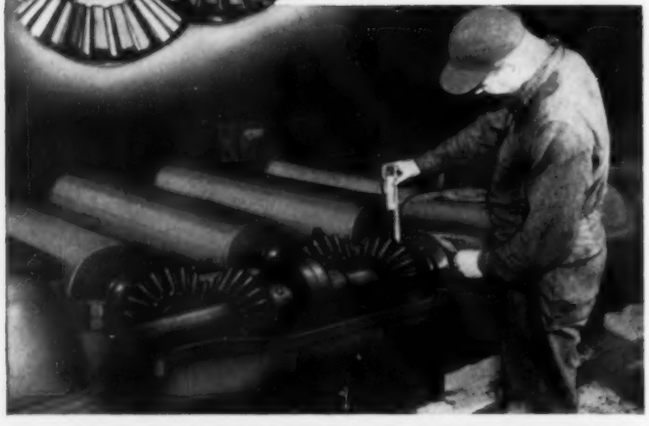
TREADWELL CONSTRUCTION CO.
MIDLAND, PENNSYLVANIA

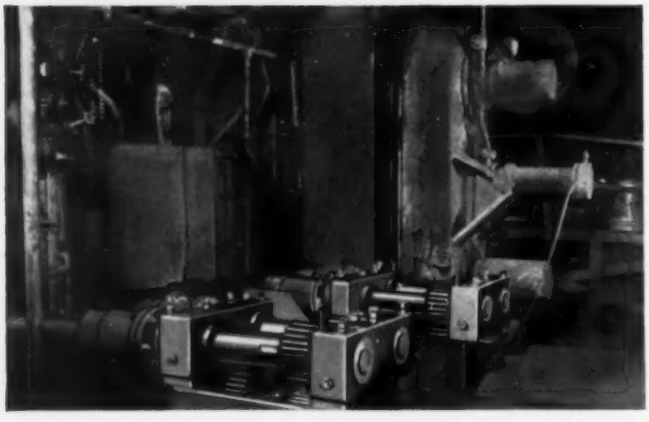
SALES OFFICES

208 S. LaSalle Street
CHICAGO 4, ILL.
CEntral 6-9784

140 Cedar Street
NEW YORK 6, N. Y.
WOrth 4-3344

1217 Farmers Bank Building
PITTSBURGH 22, PA.
ATlantic 1-2883



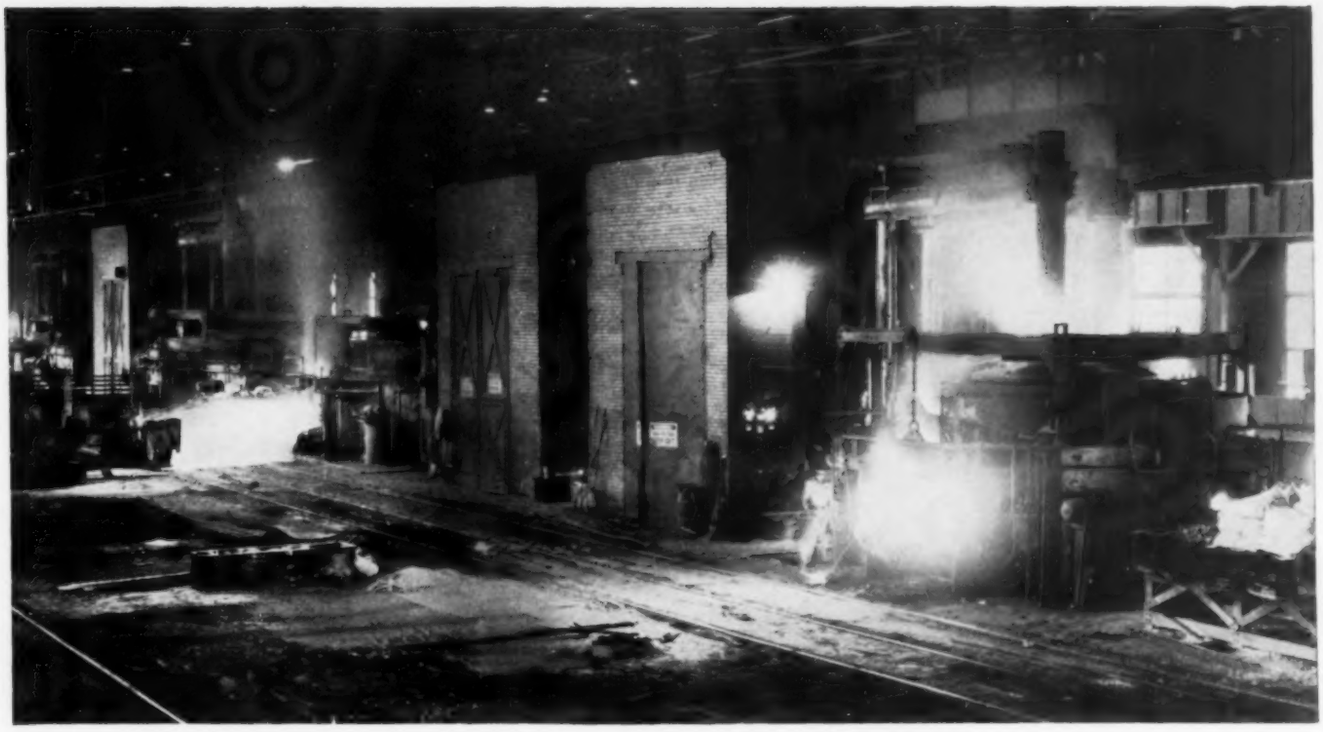


THE Midland Plant of Crucible Steel Company of America has used NE gear drives for many years. The satisfactory performance and long life in their round-the-clock duty has resulted in many repeat orders. NE engineers and craftsmen carefully follow each step in production from raw material to finished product. The blanks are cast in our own foundries. They are heat treated under the most careful control, and modern gear cutting machines cut and finish them to specification. On many of their heavily loaded drives Crucible's gear specifications are "Neloy Flame Hardened". You are welcome to our revised bulletin No. 9 "Neloy and Neloy Moly for Industrial Gear Drives". Consult with us on your gearing requirements—It will pay you a substantial profit.

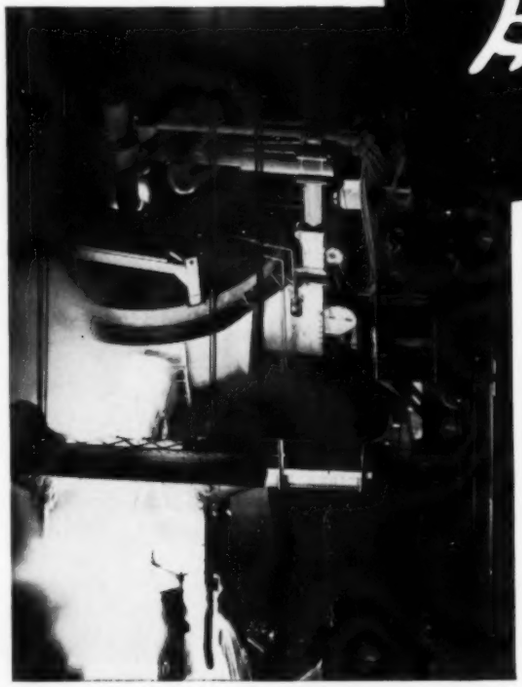
NATIONAL ERIE CORPORATION

ERIE, PENNSYLVANIA • U. S. A.

NE



at Crucible's Midland Works



Heroult ELECTRIC FURNACES

prove their dependability

● Back in 1940, Crucible Steel Company of America installed two Type 35 Heroult electric furnaces at its Midland Works. A year later, they duplicated the order. Today all 4 Heroult's are running full tilt after nearly ten years of continuous service!

Such a record proves beyond question what many other large mills have long known: that for dependability and economy, you can't find a more efficient furnace than the Heroult.

For detailed information about the superiority of modern Heroult electric furnaces for the production of high alloy, stainless and rimming steel, just call our nearest Contracting Office. A special booklet comprehensively covering the complete line is available for the asking.

AMERICAN BRIDGE COMPANY

General Offices: Frick Building, Pittsburgh, Pa.

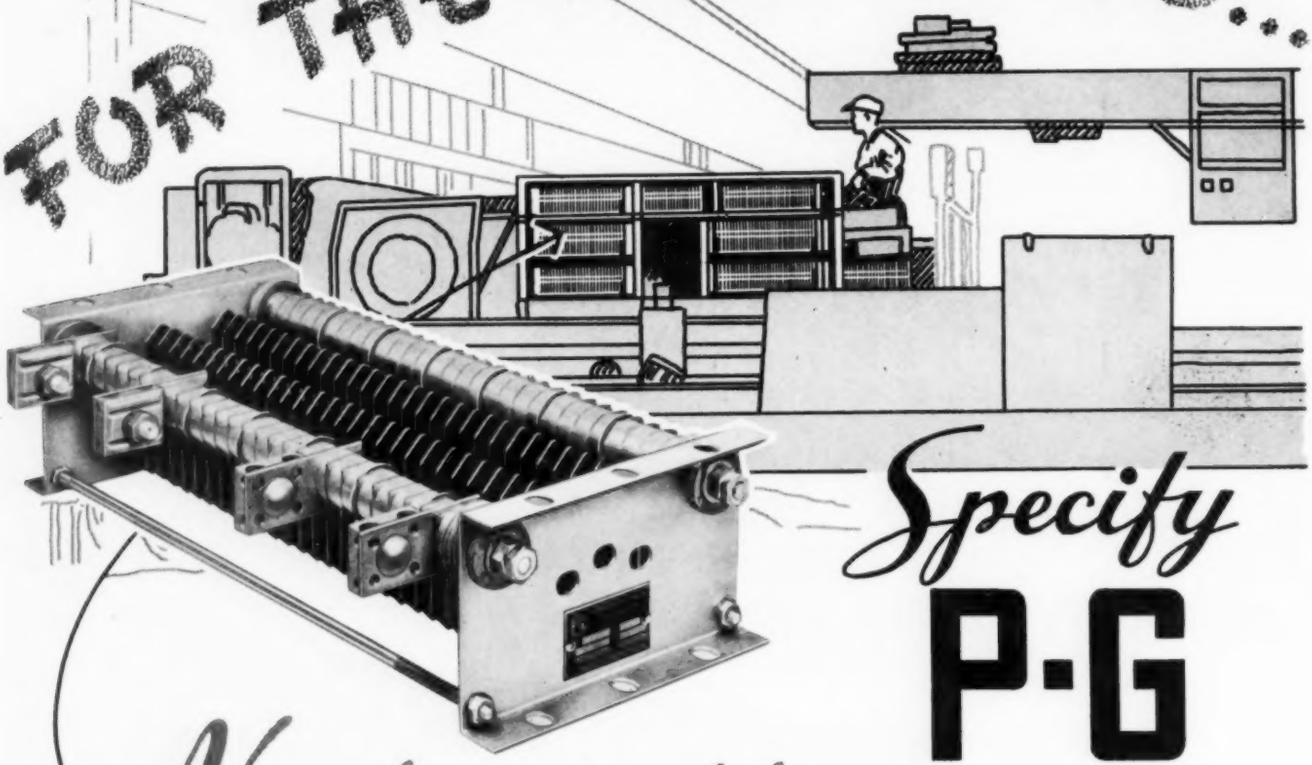
Contracting Offices in: AMBRIDGE · BALTIMORE · BOSTON · CHICAGO · CINCINNATI
CLEVELAND · DENVER · DETROIT · DULUTH · ELMIRA · GARY · MINNEAPOLIS · NEW YORK
PHILADELPHIA · PITTSBURGH · PORTLAND, ORE. · ST. LOUIS · SAN FRANCISCO · TRENTON
UNITED STATES STEEL EXPORT COMPANY, NEW YORK

USS TRADE MARK

AMERICAN BRIDGE

UNITED STATES STEEL

FOR THE TOUGH JOB...



Specify

P-G

Nonbreakable RESISTORS

Built of steel and mica, there is nothing delicate or fragile about a P-G Resistor. When used for the troublesome jobs that seem to plague every maintenance department, continuous Trouble-Free Service may be expected.

P-G Resistors are not affected by vibration set up by various kinds of mobile steel mill equipment. Neither are they harmed by moisture laden or corrosive atmospheres. In addition there is provision for expansion coupled with adequate ventilation to dissipate the heat of operation.

Often, after one test installation in that tough spot, P-G Steel Grid Resistors are specified not only for repair and maintenance replacements but for new work as well.

Complete data in
BULLETIN No. 500
Copy on request

P-G

The Nonbreakable Steel Grid Resistor

THE POST-GLOVER ELECTRIC COMPANY

• ESTABLISHED 1892 •

221 WEST THIRD STREET, CINCINNATI 2, OHIO

Up to 22 times more operations without re-lubricating

HOMESTEAD-REISER *Self-Sealed* LUBRICATED PLUG VALVES

TEST RECORD

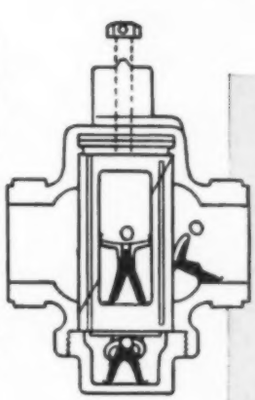
VALVE	NO. OF OPERATIONS Without RE-LUBRICATING
VALVE "A"	5
VALVE "B"	33
HOMESTEAD-REISER VALVE	**110**

Each valve assembled with the manufacturer's recommended lubricant. Test made on 75 lb. air pressure.

This comparative test of a Homestead-Reiser Valve and two other well-known lubricated plug valves showed that the Homestead-Reiser Valve remained drop-tight through twenty-two times more operations than Valve "A" without re-lubricating, and through three times as many operations as Valve "B". That means that Homestead-Reisers require less attention, and give greater economy of lubricant.

Prove the superiority of Homestead-Reiser Valves to your own satisfaction, by installing a few in your plant, side by side with any other lubricated plug valve. They may be had in both semi-steel and cast-steel, sizes ½" to 12" for steam working pressures to 150 pounds, or oil-water-gas to 200 pounds.

Write for new catalog 39-5, and for prices on your requirements.



"Self-Seald" MEANS

. . . that in addition to a full-port lubricant seal, the wedge-action of the plug under line pressure forces the finished surfaces of the plug outward, and constantly presses them against the seating surfaces of the body, thus keeping them always in intimate contact. The plug automatically adjusts itself for wear, assuring extra long life, maximum leakless service, and lubricant economy.

HOMESTEAD VALVE MANUFACTURING CO.
"Serving Since 1892"

P. O. Box 21 **CORAOPOLIS, PA.**

PENNSYLVANIA ENGINEERING CORP.

NEW CASTLE, PENNA.

BUILDS

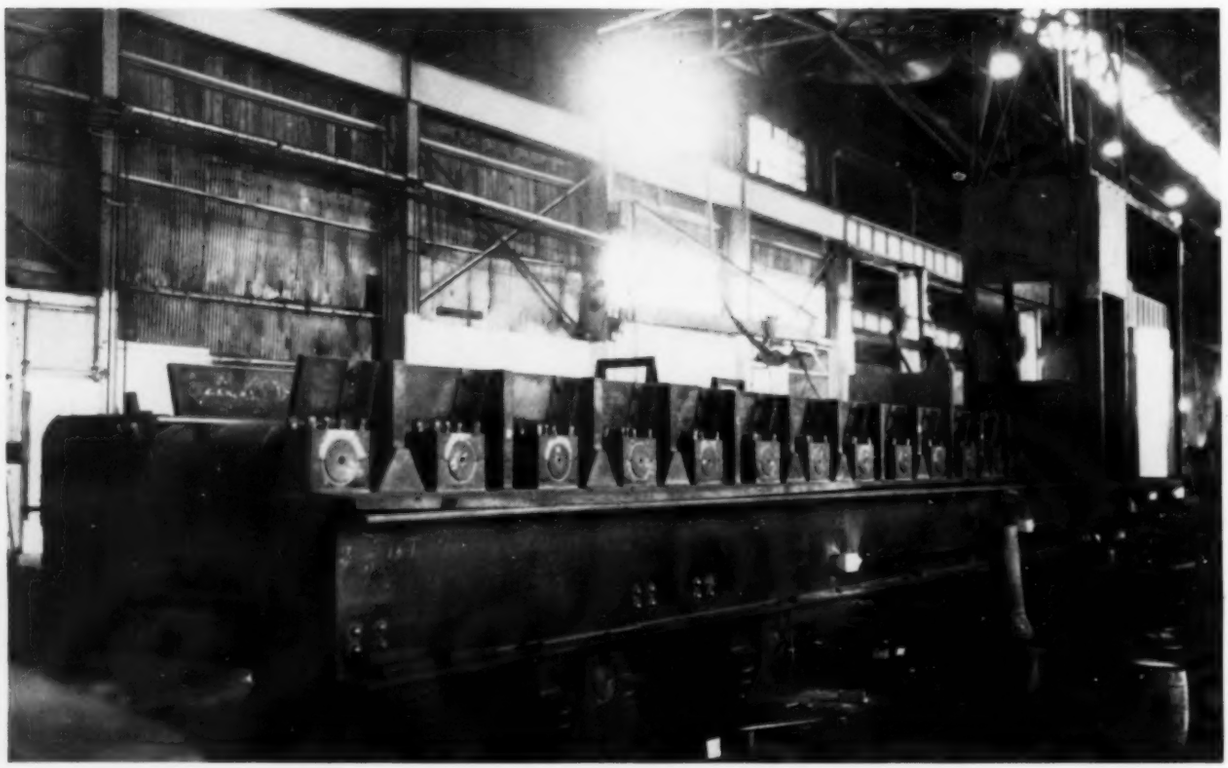
ROLL TABLE TRANSFER CAR

AND

AUXILIARY EQUIPMENT

FOR

CRUCIBLE STEEL CO'S PLANT AT MIDLAND, PENNA.



ROLL TABLE TRANSFER CAR — CRUCIBLE STEEL CO'S MIDLAND PLANT

The Pennsylvania Engineering Corporation with 50 years of experience is qualified to design and fabricate all kinds of special cars for the steel mills, including Ingot Mould Cars, Charging Box Cars, Hot Metal Transfer Cars, Slag Pot Cars, Roll Table Transfer Cars, Converter Jack Cars, Slag Cars, Scrap Transfer Cars, Bottom Oven Cars, Material and Stock Transfer Cars, Billet Transfer Cars, Skip Hoist Cars and Ingot Pouring Ladle Transfer Cars. Cars can be furnished Self Propelled and Self Tilted when required.

DESIGNERS, FABRICATORS AND ERECTORS OF STEEL MILL EQUIPMENT

Clevelands

SERVE CRUCIBLE AT MIDLAND

CRUCIBLE is one of the many steel companies that know Cleveland from long experience as The Dependable Worm Gear Speed Reducer. Crucible installed its first Cleveland in 1929.

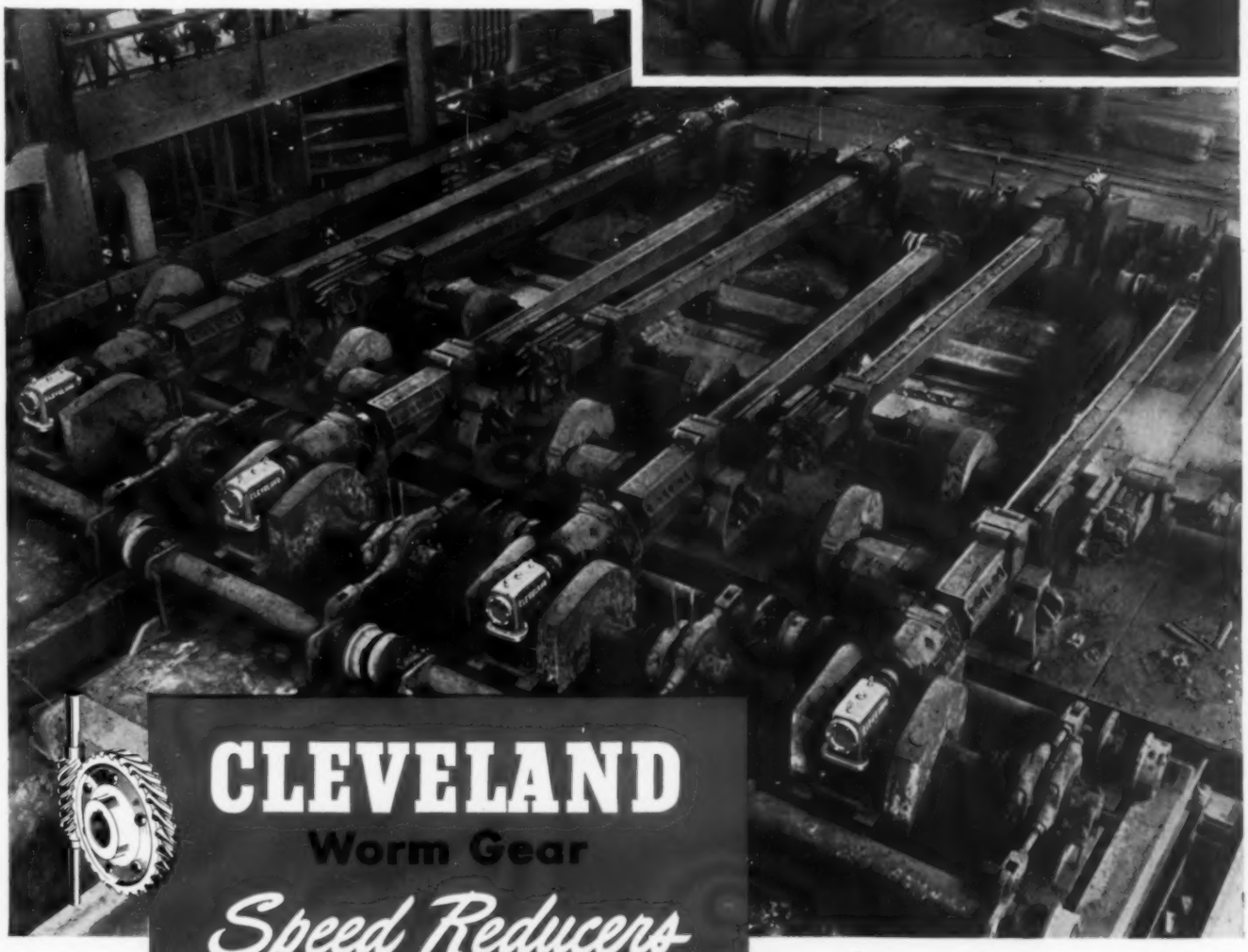
For 38 years Cleveland has devoted its manufacturing facilities exclusively to the production of high grade worm gear drives.

The complete Cleveland line includes standardized worm gear reducers in a variety of types and a wide range of speeds, ratios, and power capacities. Worm and gear sets are available also and special units are designed to meet unusual conditions.

Wherever they serve, as pit cover drives or with any other kind of motorized steel mill equipment, you can depend on Clevelands to give uniform, trouble-free performance.

The Cleveland Worm & Gear Company, 3278 East 80th Street, Cleveland 4, Ohio.

Affiliate: The Farval Corporation, Centralized Systems of Lubrication. In Canada: Peacock Brothers Limited.



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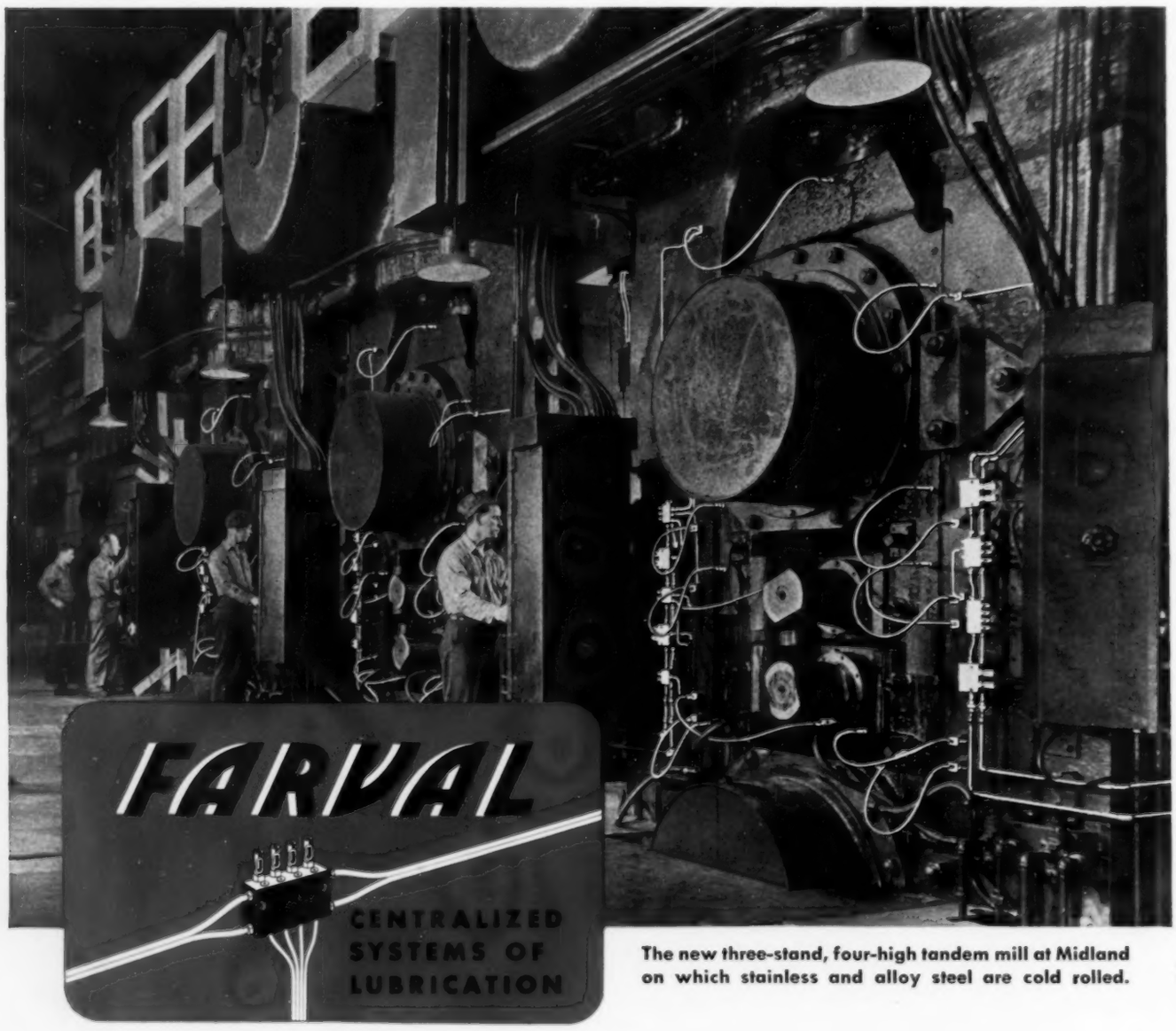


The new three-stand, four-high tandem mill at Midland on which stainless and alloy steel are cold rolled.

COLD ROLLING OF TINPLATE

. . . . test studies such as the ones in this paper are important factors in attaining maximum mill operation efficiency . . . .

By G. E. STOLTZ
and
J. W. BRINKS
Westinghouse Electric Corp.
Pittsburgh, Pa.

▲ THE advance in the art of cold rolling tinplate has been one of the most outstanding developments in industrial production. To change from rolling this product on hand mills at a delivery speed of 230 fpm, with an output of less than one ton per hour per mill, with practically the same number of men that now operate a five-stand tandem mill at 4000 fpm, with an output of one ton per minute, of necessity, involves the solution of a number of rather difficult problems.

In 1940, a part of the curve shown in Figure 1 which includes representative delivery speeds of tandem tinplate mills up to 2300 fpm was plotted. The first mill of this type was placed in operation by the Wheeling Steel Corp. in 1928. Not all of the mills installed are represented by points on this curve but those shown indicate the delivery speed that prevailed at that time.

After plotting this curve, it was naturally questioned as to whether the ultimate in speed of rolling tinplate had been attained or were still higher speeds to be utilized. As shown on Figure 1, we drew one dashed line horizontal at 2300 fpm and another as an extension of the curve including all the points with the exception of the one representing the first Wheeling Steel installation in 1928. Our prediction at that time was that we could expect the curve to continue to rise somewhat, extending between the two dashed lines, possibly reaching an ultimate speed of 3000 fpm.

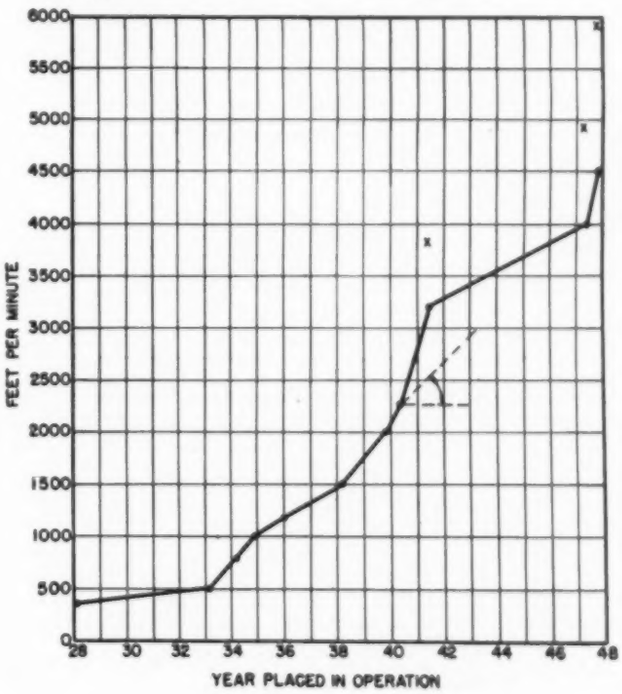
Experience since this date has shown that we were entirely too conservative. In May, 1941, the Carnegie-Illinois Steel Corp. put in operation a five-stand cold mill at their Irvin Works having a nominal speed of 3300 fpm and a maximum possible speed of 3750 fpm. In March, 1946, the Weirton Steel Co. placed in operation their No. 6 five-stand tandem cold tinplate mill having a nominal speed of 4000 fpm and a maximum possible speed of 5000 fpm. Immediately after this, the Jones and Laughlin Steel Corp. installed a mill having a nominal speed of 4500 fpm and a maximum rated speed of 6000 fpm. The points representing the nominal speeds of all of these mills are above the dashed line extension showing the trend between 1933 and 1941, and represent a considerable advance in speeds over the experience obtained on previously installed mills.

One noteworthy change in the procedure of placing these mills in production occurred. Up to and including the 2300 fpm, four-stand Weirton mill, it was found practical to operate at the maximum rated delivery speed of the mills from their very start. The Irvin No. 2, Weirton No. 6 and the Jones and Laughlin mills have rolled on occasions at their maximum speeds but most of the time they are run in the neighborhood of their respective normal speeds. This may indicate that we have reached the ultimate in speed or that we have come to the place where a study should be made if further increase in tonnage is to be obtained. Such an increase might logically be derived from higher speeds, or from more efficient handling with present speeds.

In order to obtain operating data on a modern high speed mill, a test was made on the No. 6 mill at the Weirton Steel Co. While we have been asked to prepare this paper, the test was a cooperative one and the Weirton Steel Co. is to be commended for the time and effort they gave in making this test, their willingness to make the mill available, and to have the data presented before the Association of Iron and Steel Engineers for the benefit of the entire industry.

Graphic records were obtained of kilowatt input to the motor-generator sets, motor armature amperes,

Figure 1 — The representative delivery speeds of tandem cold tinplate mills have increased markedly in the last few years.



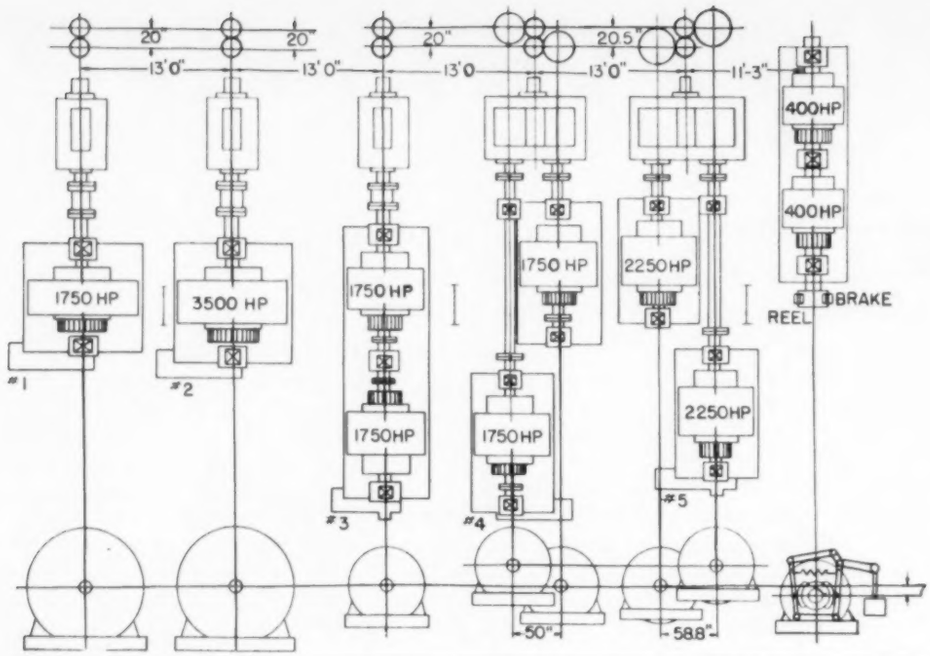


Figure 2 — General arrangement of electrical drives is given schematically in this figure.

voltage, speed, roll pressure of each stand, as well as tension between stands and strip thickness out of No. 1 and No. 5 stands.

ARRANGEMENT OF DRIVES

Figure 2 is a schematic plan view of the driving equipment. Stands 1 and 2 utilize single armature motors direct connected to the work rolls through pinion housings. The speed of stands 3, 4, and 5, as well as the reel, are high and the horsepower required great enough to require multi-armature motors. Stand No. 3 is driven by a double armature motor direct connected to the working rolls through a pinion housing. Duplicates of these motors are used on stand No. 4 except they have individual offset gears to each of the work rolls. The gear units are designed to have each motor drive its work roll separately, or a locking gear can be installed to tie the two drives together. The same arrangement is used on stand No. 5 except the horsepower rating is increased. Two papers have been published in the 1948 bound volume of the *Iron and Steel Engineer*, one by C. J. Klein and the other by A. F. Kenyon, which describes this mill and its electrical equipment in considerable detail.

POWER REQUIREMENTS

When consideration is being given to the installation of a new mill of this type or increasing the speed of an existing mill, one of the most important subjects to be considered is the power required to drive the mill. Power readings were taken for this purpose on five different tinplate schedules. The results are shown on Figure 3 plotted as horsepower hours per ton against elongation of the strip. The horsepower values used are output of the main drive and reel motors. This curve checks very well with previous information published by the Association of Iron and Steel Engineers.

DATA SHOWN ON GRAPHIC CHARTS

If a mill of this type could be operated continuously at its normal running speed, many of the problems of operation, and application of electrical equipment would be eliminated. The difficult part in rolling strip on such a mill occurs during the slowing down, threading, and accelerating periods. Weirton rolls coils having a weight of 25,000 to 30,000 pounds made by welding several hot bands together. When this test was made, it was their practice much of the time to slow down when the welds passed through the mill. This procedure enabled us to study the mill performance during periods of speed change as well as at both normal and slow speeds, with strip in all the rolls for an extended time. Figure 4 is a record taken from graphic charts of speed, armature current of each motor, strip thickness out of No. 5, tension between stands and roll pressures. The curves show performance at normal speed, just before and after slowdown, as well as at slow and changing speeds.

The speed of each stand closely follows the bus voltage. The normal rolling delivery speed out of No. 5 was 3300 fpm and during the slow period 600 fpm.

The current curve on stand No. 1 shows a small decrease in armature current due to deceleration as well as a small increase due to acceleration. These values increase from stand to stand towards the delivery end of the mill. On No. 5 the current during the decelerating period came close to zero. This illustrates why it is important to keep the flywheel effect of the finishing stands to a minimum.

Another significant fact shown by these current curves is that on No. 1, the armature current during the slow period remained near zero. The armature current of No. 2 during the slow operation was appreciably less than during normal operation. On Stand No. 3 it is about the same, but on No. 4 the motor drew more current during the slow period than when rolling at normal speed. The current on No. 5 was practically the same at slow and normal speeds. This indicates that

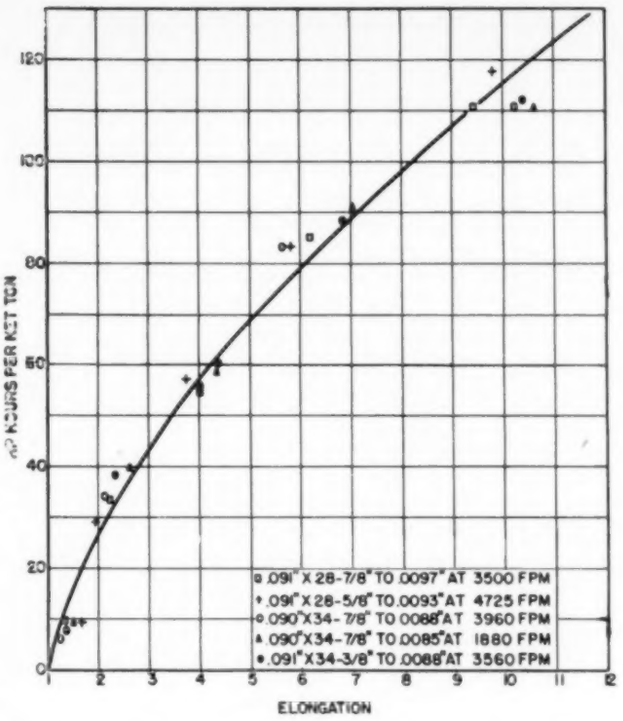


Figure 3 — Power requirements for a cold strip mill are here plotted against elongation.

the mill operators increased the tension between stands at the entry end of the mill particularly between 1 and 2, to offset overgage out of No. 5. This we believe is very good practice.

The tension between all stands increased appreciably during the slow speed period. The individual values of increase in tension at slow speed are as follows:

Stand	Per cent in tension
1-2	55
2-3	43
3-4	88
4-5	62

We were surprised to find that the roll pressure meters showed a decrease of pressures during the slow speed operation. With overgage at slow speed, we expected the roll pressures to increase just as the tension between stands increased. Later tests were made with entirely different pressure meters which substantiated the fact that the roll pressures do decrease as the mill is slowed down.

In order to check the change in roll pressures more carefully with variation of both strip thickness and speed, it was decided to connect a graphic meter to the micrometer gage used between 1 and 2 and to calibrate the graphic strip thickness meters so that overgage of 0.010 in. could be recorded on the charts. These instruments do not read as accurately for small changes of strip thickness as the indicating meters installed on mill housings, but in this study, we were more interested in analyzing the causes and amount of off-gage.

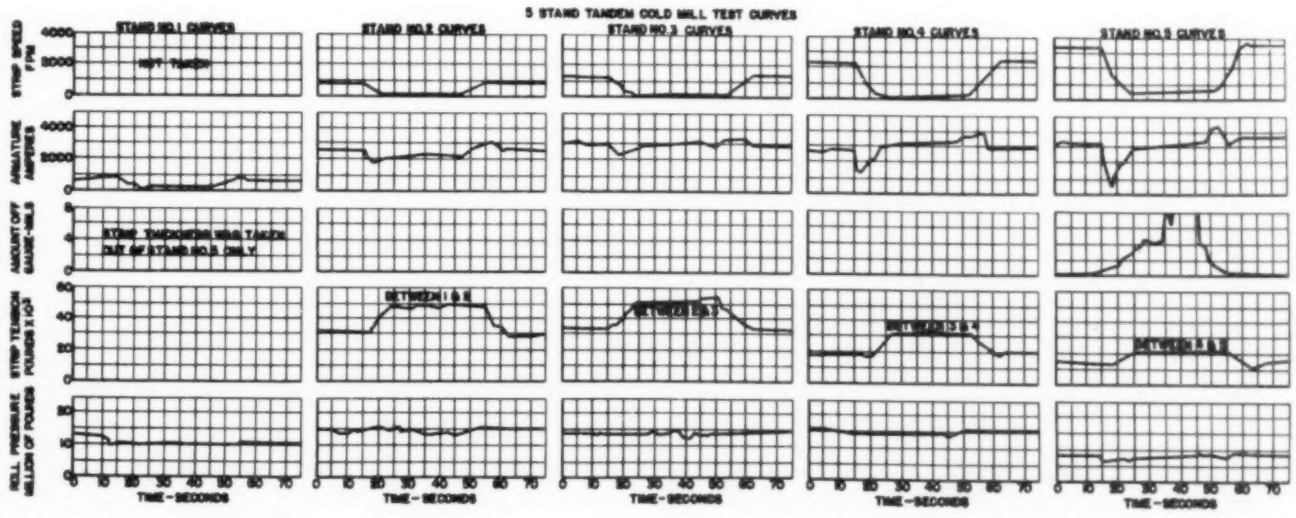
The strain gages initially used to record roll pressures were mounted on the side of the mill housings. The cross section of the housings is such that with a 1,500,000 pound roll pressure the tension in the housing was only 450 psi. This resulted in very little elongation and since our pressure gages were to be installed temporarily for the test only, it was decided to utilize pressure gages mounted between the screws and the back-up bearing housings.

The Morgan Construction Co. offered to install such gages and provide the necessary graphic meter. From this point on they joined Weirton and ourselves in making the test. Records of roll pressures as obtained with their equipment proved to be of considerable value.

OVERGAGE

When our tests were continued, it was decided by Weirton that they would attempt to hold gage out of No. 5 at slow speeds by changing the screw on No. 1 stand and the tension between stands 1 and 2. Figure 5 shows some of the results obtained. This data consists of certain graphic records taken on two coils while the mill was slowed down for a weld. In the first instance,

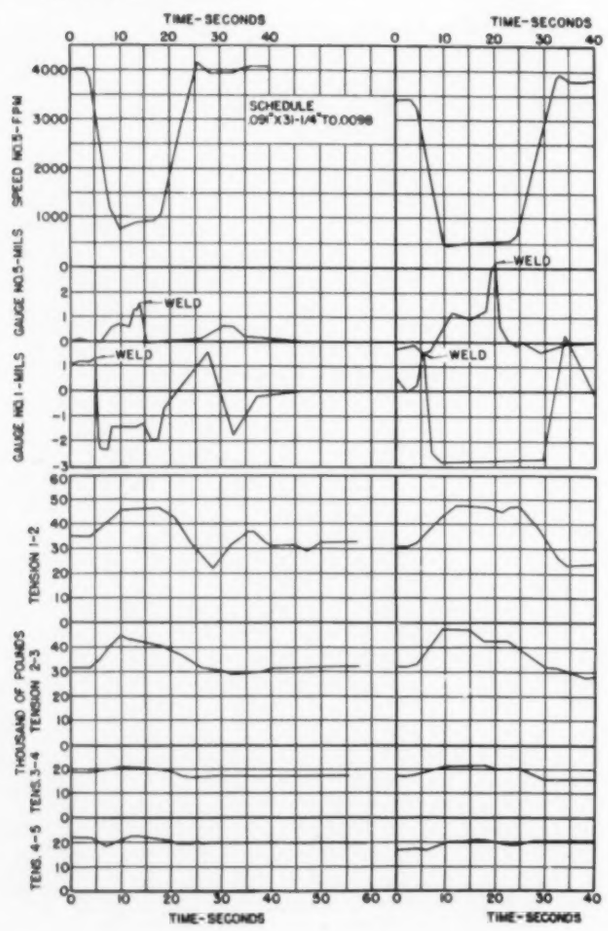
Figure 4 — Performance of the cold mill, as measured, is given in this diagram for the five-stand mill.



the mill was operating at 4000 fpm and the speed was dropped to 800 fpm. At the instant the weld passed through No. 1 stand the thickness of the strip decreased 0.0035 in. This is due to the difference in thickness of the trailing end of the hot band about to be completed, and the leading end of the new coil. The operator was manipulating his screwdown and tension to assist in holding gage out of No. 5. The overgage at the very end of the old strip out of No. 5 was 0.0015 in. but immediately dropped to on gage when the new strip was delivered from the last stand. While the operator manipulated No. 1 screws only, this also indirectly caused tension between stands 1-2 and 2-3 to change in value to assist in obtaining the desired strip thickness. This resulted in very little increase of tension between stands 3-4 and 4-5 as shown on the charts.

The curves to the right on this figure show substantially the same performance although in this case the gage out of No. 5 increased 0.003 in., but immediately, when the new strip came through, it was quickly brought to normal gage. Again very little excess tension was obtained between 3-4 and 4-5. While it is not possible to hold gage out of No. 5 under all circumstances, the results of these two instances are as near perfect as is practical. Holding gage out of No. 5 by changing No. 1 screws and tension between No. 1 and No. 2 is a logical method as it avoids manipulating tension between No. 4 and No. 5 where the section is small and the steel brittle. Few breaks occurs between No. 1 and No. 2 where the section is large and not so brittle.

Figure 5 — Data shows tension and overgage during slowdown of mill.



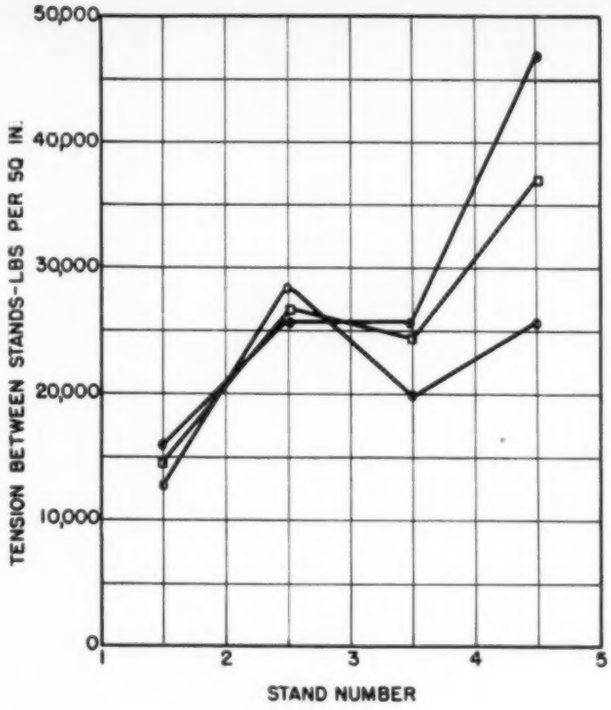


Figure 6 — The tensions at normal rolling speeds between stands are given in the diagram.

We would not expect to hold gage so accurately on the extreme trailing end of a coil, as tension is lost as it passes from stand to stand. Also the mill speed is usually lower than when a weld goes through the mill. Neither would we expect such good results when the leading end of a new coil is threaded through the mill, but we see no reason why No. 1 screw and the tension between No. 1 and No. 2 cannot be used to get on gage as quickly as possible.

TENSION

The values of tension in Table I between stands is taken from Figures 4 and 5, the first before an effort was made to hold gage during slowdown and the second and third readings after the screwdown of No. 1 and tension between 1 and 2 was manipulated to hold gage out of No. 5.

It will be noted the per cent increase in tension at slow speed between 3-4 and 4-5 on the first set of readings is greater than between 1-2 and 2-3. The second and third tabulations which are examples of an effort to hold gage shows the reverse, that is, the per cent increase between 3-4 and 4-5 is less than the corresponding per cent increases between 1-2 and 2-3. The full speed tension per square inch between 3-4 and 4-5 is greater on the last two sets of readings than on the first. This means that more work is being done by tension and less by roll pressure, which would also assist in producing less overgage from the change of coefficient of friction between the strip and roll surface.

The tension at normal speed expressed in psi for these three coils is shown in Figure 6. The range of tension

between stands 2-3 and 3-4 is from 20,000 to 30,000 pounds. This we believe is a good practical range to use. The tension used between 1-2 seems low but it leaves a good margin for an increase to limit the overgage when the mill is slowed down. The values between 4-5 are higher than often used on other mills, but is very desirable practice, if the strip will withstand this amount of tension without an undue number of breaks. The values shown in Figure 6 are typical of Weirton's practice and the number of breaks that occur are not unusual.

Reduction of steel is obtained by a combination of roll pressure and tension. In general, we believe it is desirable to use as much tension as is practical. Tension tends to elongate the steel uniformly across its width. Rolls deflect and tend to produce heavier gage in the center of the strip than at the edges. This tendency must be offset by grinding the rolls with crown in the middle. Several coils usually must be rolled before the mill is brought up to temperature to effect the full value of the crown to produce flat sheet. The greater the percentage of reduction obtained by tension, the less trouble it is to obtain the temperature for the correct crown of the rolls. Reduced roll pressure also contributes toward less wear of the rolls, and less tendency to have metal pick up.

The amount of tension that can be used, of course, is limited by the character of the steel; as the presence of bad edges, holes in the strip, etc., which may make it necessary to reduce tension.

TABLE I — TENSION VALUES

Previous to attempt to hold gage by manipulation of No. 1 screws and tension between No. 1 and No. 2 — 0.091 x 35 in. to 0.0096 in

Stands	Full speed		Total at threading speed	Per cent increase
	Total	Psi		
1-2	31,000	12,850	48,000	55
2-3	35,000	28,500	50,000	43
3-4	17,000	19,800	32,000	88
4-5	13,000	25,700	21,000	62

After attempt was made to hold gage by manipulation of No. 1 screws and tension between No. 1 and No. 2 — 0.091 x 31¼ in. to 0.0098 in

Stands	Full speed		Total at threading speed	Per cent increase
	Total	Psi		
1-2	34,500	15,900	45,000	30
2-3	31,500	26,100	44,000	40
3-4	18,500	25,600	21,000	14
4-5	22,000	46,800	22,000	0
1-2	31,000	14,300	47,500	53
2-3	32,000	26,500	47,500	48
3-4	17,500	24,100	21,500	22
4-5	17,500	37,200	21,500	20

Figure 7 — Roll pressures, as determined by the graphic meter, are given in this chart.

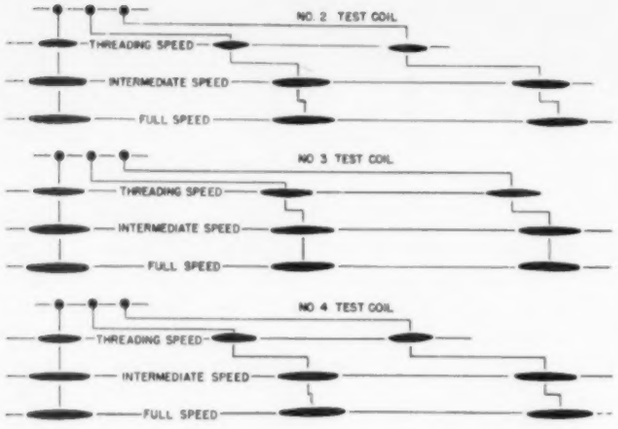


Figure 8 — Sketch shows relative shape and spacing of test holes in three coils when run through the mill at three speeds.

ROLL PRESSURE

Figure 7 is a record of roll pressures as obtained from the graphic meter. The first week the two pressure gages were installed on stand No. 5, the second week on stand No. 4 and on back to the first stand on consecutive weeks. It was necessary to change the position of the instruments at periods when back-up roll changes were made.

There are a number of interesting facts to be obtained from the pressure charts. The cyclic variation as traced by the pen of the instrument is indicative of non-concentricity, flat, or rough spots of the back-up rolls. The frequency increases from No. 1 to stand No. 5 due to increase of speed. These curves show greater amplitude at slow speeds than when the mill is operating at its nominal rolling speed. The actual amplitude is shown at the slow speed as the time constant of the graphic meter was not fast enough to record the full swing at the top rolling speeds. The value of pressure variation on No. 5, at times is approximately 100,000 pounds.

There is also a six second cycle variation of roll pressure on No. 5. This is caused by a difference in the diameter of the back-up rolls. When the non-concentricity, or flat spots mesh with each other, large amplitudes are produced, but when out of mesh they tend to cancel the effect of each other; such variations may occur on any of the stands, depending on the condition of the rolls.

At times there is a peak pressure shown when the rolls pass over a weld. This indicates that the hardness of the weld is greater than the adjacent metal, so that the weld is not reduced in thickness as much as the rest of the strip. At times, it is sufficient to appreciably increase the roll pressure. This is shown rather clearly at the left of the chart on stand No. 4 where the increase in pressure is 50,000 pounds. This results in quite a blow on the strip immediately following the weld.

Usually there is an appreciable decrease in pressure in going from the trailing end of one strip to the leading end of the following strip. On the chart for No. 1 stand to the right, the drop in pressure is 90,000 pounds and to the left of this same chart a drop in pressure of 42,000 pounds is obtained.

The taper in thickness from the leading to the trailing end of the hot bands is due to decreasing temperature as the strip is rolled in the hot mill. Sometimes, it can be easily noted that the roll pressure gradually increases from the leading to the trailing end of an individual coil between welds.

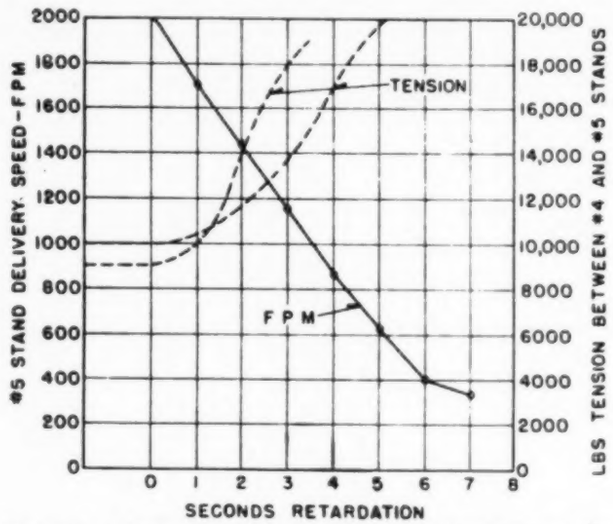


Figure 9 — Strip tension is given during slowdown of five-stand mill.

Another interesting fact brought out by these curves is that the roll pressure decreases as the mill slows down, even though the strip thickness increases during this period. The magnitude of these values vary as is shown on the charts, and as recorded in Table II.

It occurred to us that this drop in roll pressure with the speed of the mill might be due to a decrease in the thickness of the oil films in the back-up bearings, otherwise we would expect the pressure to increase if overgage is obtained.

TABLE II

TYPICAL EXAMPLES OF REDUCTION IN ROLL PRESSURE AS SPEED IS REDUCED FOR WELDS

Stand	Lb at full speed	Lb at slow speed	Reduction in lb	Per cent reduction
1	1,348,000	1,008,000	340,000	25.0
1	1,386,000	1,184,000	202,000	14.6
2	1,638,000	1,550,000	88,000	5.4
3	1,310,000	1,186,000	124,000	9.5
4	1,600,000	1,512,000	88,000	5.5
5	1,481,000	1,323,000	158,000	10.6
5	1,638,000	1,562,000	76,000	4.6

CAUSES OF OVERGAGE

One possible cause of overgage is that the coefficient of friction between the strip and the roll surfaces increases as the mill is slowed down. If this is true, it would be natural to expect a greater increase in overgage in the delivery end of the mill than in the entry end. On a mill rolling steel at 4000 fpm which drops to one-tenth of this speed for threading, the fifth stand would have a change of 3600 fpm. If No. 1 stand has a normal rolling speed of 600 fpm, it would change through a speed range of 540 fpm. The fact that No. 5 changes through a much greater range may explain

why greater build-up of tension under normal conditions is obtained at the delivery end of the mill.

Several years ago, we made a test on a five-stand mill where we drilled holes in the strip before it passed through the mill. Figure 8 shows the elongation of these holes as well as the distance between the holes at threading speed, intermediate speed, and at full speed of 1640 fpm. On No. 2 test coil, 66 per cent overgage was obtained at threading speed and 3 per cent at intermediate speed. On test coil No. 3, 24 per cent overgage was obtained at threading and 0.04 per cent at intermediate speed. On No. 4 test coil, the overgage at threading speed was 63 per cent and 3 per cent at intermediate speed. This shows that the overgage is obtained and that it may vary over a wide range.

Figure 9 shows the increase in tension between stands 4 and 5 of a five-stand mill having a nominal rolling speed of 2000 fpm. In one instance when the tension between the last two stands at full speed was 10,000 pounds, this tension was increased to 20,000 pounds by

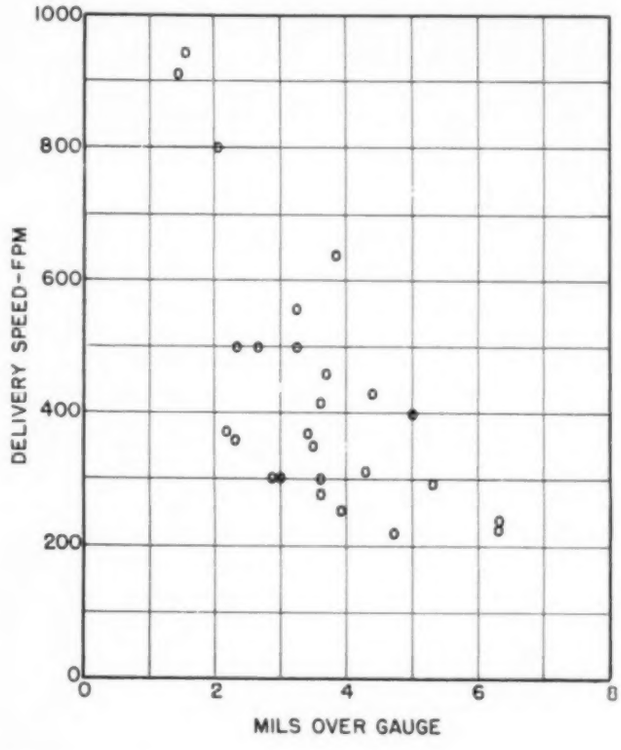


Figure 10 — Variation of gage with delivery speed is given in the diagram.

the time the mill speed was reduced to 600 fpm. On another coil where the tension was 9000 pounds between the last two stands, this tension doubled by the time the mill was reduced to 1150 fpm. This increase in tension as the mill slows down is no doubt due to overgage. If this is true, and we believe it is, this is another indication that the amount of overgage is not consistent.

A study was made of the Weirton charts showing strip thickness out of No. 5 and the results plotted on Figure 10. This shows that in most cases overgage is not obtained until the mill has been slowed down to 500 fpm, although small amounts of overgage sometimes occur at speeds as high as 1000 fpm.

Figure 11 shows the overgage when rolling 0.0098 in. at 4000 fpm and Figure 12 shows the same when rolling 0.0088 in. strip at 3550 fpm. A varied selection of overgage records show results as plotted on Figure 13 which gives the overgage in per cent. On these last three curves, it will be noted that a line almost vertical could be drawn through the various values obtained near 500 fpm.

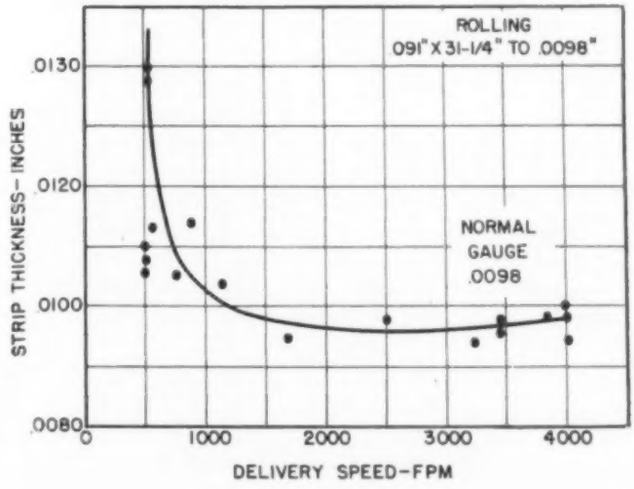
OIL FILM THICKNESS

To determine if the position of the back-up rolls changes with speed, indicator dial gages were mounted on the covers of the roll necks as shown in Figure 14. The gage was mounted so that the pointer would ride on the roll neck surface. The roll neck covers being bolted to the back-up bearing housing tends to eliminate external errors and restrict the readings obtained to changes in oil film thickness.

In one instance, gages were mounted on the back-up roll covers on the first and last stand of a four-stand sheet mill with the readings shown in Figure 14. Further decrease in oil film thickness no doubt would be obtained if readings were also taken after the mill was at rest with strip in the mill, but from full running speed to threading speed this data indicates the total reduction in film thickness was approximately 0.005 in. If we assume the elongation of the housings and flattening of the rolls at the pressures used is 0.050 in., a 10 per cent overgage from the stands might be expected; and if each stand opened approximately the same amount, an appreciable amount of overgage could be obtained out of No. 5. It must, however, be borne in mind that this effect in practice may be wholly or partially offset by increased tension between stands, and movement of screws as described in the earlier part of this paper.

An indicator gage was placed on the lower back-up roll of the fifth stand of a tinplate mill and it was noticed that a marked change in the gage reading was obtained when the mill slowed down through 500 fpm. In another instance, such a gage was placed on the lower back-up roll of the fifth stand of a mill that normally operates at 3000 fpm. Readings were taken

Figure 11 — Most of the overgage occurs when rolling at less than 1000 fpm.



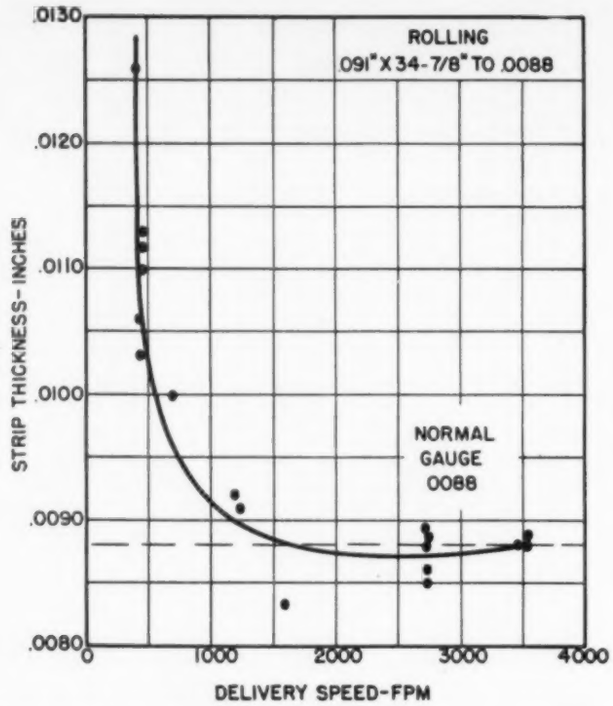
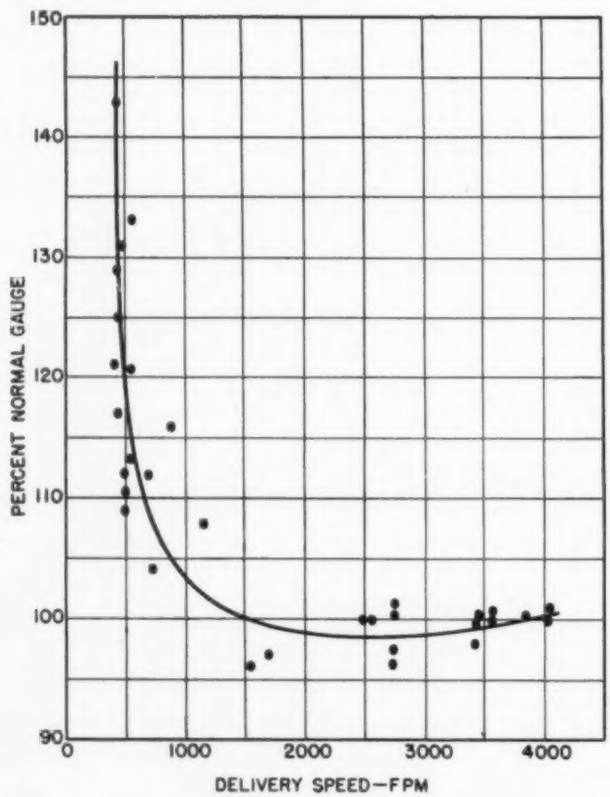


Figure 12 — Strip thickness is plotted against delivery speed in this diagram.

with no metal in the rolls, but the screws run down to build up roll pressure, and we found there was a difference of 0.003 in. in one bearing when the mill was reduced in speed from 3000 to 250 fpm.

Figure 13 — Diagram gives per cent of normal gage as a function of the delivery speed.



If further investigations show definitely that there is such a variation in oil film thickness and that it does contribute to overgage, we believe it desirable to minimize this effect by using as thin a film as is possible, and if practical by providing forced oil feed at the seat of the bearings, particularly during periods of slow speed to compensate for the reduced amount of oil carried into the bearing by the roll neck as the mill speed is reduced. This would be accomplished by positive pressure pump cylinders, the speed of which would vary inversely with the mill speed.

The fact that it is often necessary to raise the screws on No. 4 or No. 5, to start a mill after it has been standing with metal in the rolls, is evidence that there is little oil left in the bearings. We would think it to be of some advantage to always maintain a good oil film in the back-up bearings and keep the mill afloat.

There is no doubt there is a wide variation in the temperature of the oil in the bearing that cannot be avoided, but we believe it is important to hold its temperature to as near a constant value as possible. From Figure 15 it can be seen that an oil at a temperature of 100 F has a viscosity of 400, and at 145 F, 100 centipoises. This is a ratio of 4 to 1. The ability of an oil film to maintain itself is directly proportional to its absolute viscosity so that its temperature control is of considerable importance.

THE FUTURE

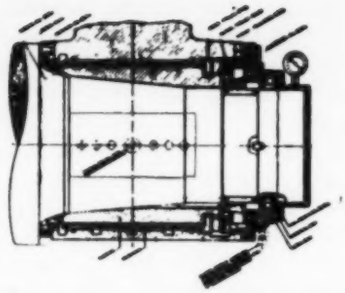
Rolling tinplate at 5000 fpm seemed to be accomplished with as great ease as at slower speeds. The horsepower required increased in proportion to the speed, but aside from this, the operation was not particularly different. If it were not for breaks, we presume tinplate would normally be rolled at 5000 fpm or more. If breaks do occur when rolling at this speed, the hazard and the amount of damage done is quite likely to be greater than when rolling at more moderate speeds. It is for this reason, as well as others such as disposing of the heat generated in reducing the steel, that operators select more moderate speeds for their average production rate.

It is important that the steel to be rolled in a mill of this type be as free from defects as possible regardless of the speed at which the mill operates. The desirability of having steel strip free of defects is accentuated if it is to be rolled on a high speed mill and with the installation of such mills, greater stress no doubt will be placed upon the importance of improving the quality of steel used for tinplate.

If breaks occur at full speed due to bad edges or holes in the strip, there is likely to be considerable loss of time, and usually the operating crews adopt a speed which seems to be most practical for the character of steel they are rolling.

For several years there has been a trend toward using longer coils either by producing larger slabs or by welding hot bands together or by a combination of both. The advantage of having a high speed mill cannot be fully capitalized unless large coils are used.

When our tests were first started it was noticed that the operators at times were not careful to immediately accelerate the mill to its full speed after a weld had



READINGS SHOWING CHANGE IN POSITION OF UPPER AND LOWER BACK UP ROLLS ON #1 & 4 STANDS OF A 4 STAND SHEET MILL WHEN SPEED IS CHANGED FROM 3000 FPM TO 250 FPM.

THE MILL WAS SLOWED DOWN IN THE MIDDLE OF TWO COILS FOR APPROXIMATELY 15 SECONDS WHEN ROLLING .072" X 31"– 12,900# COIL TO .0105" TINPLATE.

	STAND #1		STAND #4	
READING NO.	UPPER ROLL RAISED	LOWER ROLL DROPPED	UPPER ROLL RAISED	LOWER ROLL DROPPED
1	.004"	.000"	.001"	.003"
2	.005"	.0025"	.001"	.004"
TOTAL OPENING 1	.004"		.004"	
TOTAL OPENING 2	.0075"		.005"	

Figure 14 — Chart gives section of back-up roll bearing and variations caused by change in oil film thickness.

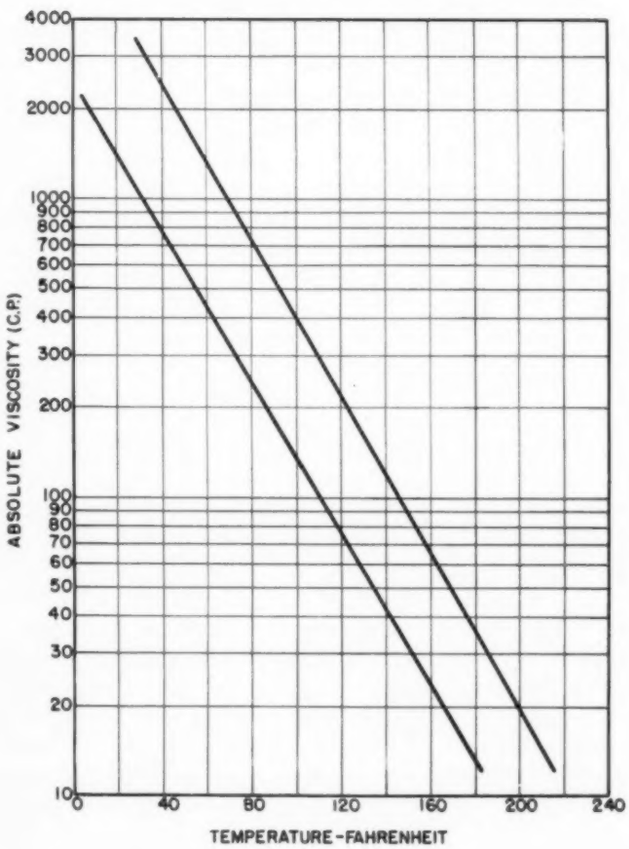
passed through the mill. In one instance it was found ten minutes were required to roll a coil. A graphic chart of the speed of No. 5 stand was used and a re-plot of the speed made on the basis of the mill being brought up to speed immediately after the weld had left the mill. It was found this coil could have been rolled in eight minutes and fifty-five seconds, which represented a saving of sixty-five seconds and an equivalent increase in tonnage output on this basis of 10 per cent. This indicates the importance of keeping the mill up to speed as much as possible.

The tests on this mill show that an overgage of from 10 to 30 per cent is common when slowing the mill down for welds and further that the amount of overgage varies. It is also our observation that the amount of overgage is greater on some mills than was found at Weirton. These tests were not continued to make a detailed study of overgage and its causes, but we feel the causes of overgage could be understood and steps taken to minimize their effect. Weirton's practice of increasing the reduction in the early part of the mill during the periods of slow-down appeals to us as being a very logical way to minimize overgage and the increase of tension between stands at the delivery end of the mill.

If the decrease in oil film thickness of the back-up bearings contributes materially to overgage, it may be possible to remedy this by providing auxiliary means of pumping oil into the bearing when the mill slows down. This, if found practical, would also have the advantage of keeping the mill afloat at slow speed.

One other possible means of increasing the tonnage output of a tandem tinplate mill would be to roll continuously. This might become practical if good welds could be assured. This would necessitate the installation of a welder ahead of the mill with the necessary looping pits or towers, and the use of two winding reels and a flying shear at the delivery end. The mill could be slowed down to 500 fpm at the time the weld is made and to permit shearing and transferring from one winding reel to the other. Depending upon the character of the welds made, the mill could be accelerated immediately upon completion of the weld or acceleration deferred until the weld passes through the mill. This would have the advantage of avoiding threading and should reduce the amount of overgage obtained.

Figure 15 — This viscosity temperature chart shows the marked change in viscosity with temperature.



DISCUSSION

PRESENTED BY

C. J. KLEIN, Chief Engineer, Weirton Steel Co., Weirton, W. Va.

J. H. HITCHCOCK, Director of Research, Morgan Construction Co., Worcester, Mass.

L. J. GOULD, Chief Engineer of Construction, Bethlehem Steel Co., Bethlehem, Pa.

G. H. RENDEL, Research Associate, Carnegie-Illinois Steel Corp., Pittsburgh, Pa.

M. A. LEISHMAN, Electrical Engineer, Steel Co. of Canada, Ltd., Hamilton, Ontario, Canada

H. W. POOLE, Manager, Steel Mill Division, General Electric Co., Schenectady, N. Y.

G. E. STOLTZ, Consulting Metal Working Engineer, Westinghouse Electric Corp., Pittsburgh, Pa.

FRANK P. DAHLSTROM, Rolling Mill Consultant, New Haven, Conn.

C. J. Klein: Mr. Stoltz and his colleagues are to be

commended for the compilation of data on the operation of tandem cold rolling mills. This information should be of considerable value in the designing and operating of present and future mills.

Figure 1 shows graphically the advancement made in the speed of rolling. This has come about by improvements in the design and manufacture of both electrical and mechanical equipment, quality of the steel, and experience obtained by the operators in taking advantage of the above conditions.

It appears at the present time that the mill equipment both electrically and mechanically is a trifle ahead of other conditions in the utilization of the higher rolling speeds at which recent mills have been developed. It will be noticed at times that the ultimate in speed is not used due to power limitations, even with the enormous-sized motors now in use in the higher speed mills.

One of the major disadvantages of operating a high-speed mill is the use of comparatively light-weight, one-slab coils, or of built-up coils, in that frequent acceleration and deceleration of the mill is required, as welding of the coils in the pickling line has not improved to a point where a 100 per cent nonbreakage of the strip through the tandem mill can be obtained. Therefore the roller on the tandem mill is prone to slow down the mill to speeds of about 500 to 1000 fpm to reduce the possibility of breakage and, if breakage does occur, to minimize the damage to the mill equipment.

The slowing down of the mill speed for passing welds imposes a condition on the equipment and the operator that requires the ultimate in ingenuity to roll a strip within gage tolerances. The variables causing this condition are numerous and include such items as gage of strip on each side of the weld, variable hardness of the strip at this point, changes in tension between roll stands due to slowdowns, thickness of oil film in bearings, and between strip and work rolls, change in shape of rolls, workability of strip at reduced speeds, springs of mill due to change in total rolling pressure required, amount of cooling water applied to strip, and so forth.

John H. Hitchcock: Mr. Stoltz's and Mr. Brinks' paper represents an interesting attempt to explore a new field in connection with the special problems that arise in the operation of a tandem cold strip mill at high speed.

The authors are to be commended for their efforts to illuminate this zone of darkness, and we applaud also the action of Weirton Steel Co. in sponsoring the tests and making their mill available for the purpose. We welcome the opportunity to cooperate in such enterprises as this, in the interest of increasing the fund of accurate knowledge which is essential to continued progress in the rolling mill industry.

The data presented in this paper provide an indication of the extent to which thickness of product may vary during periods of retardation, slow speed running, and reacceleration.

The paper also mentions some of the factors which contribute to gage variations. In my opinion the most significant observation in the paper is the statement that the amount of overgage during slow speed operation varies widely on a particular mill and still more widely between different mills. This statement emphasizes the vital point that the factors which lead to variations in gage are at least partially uncontrolled and are perhaps uncontrollable.

To appreciate the complexity of this problem, consider first a single four-high stand, in which the thickness of product obviously depends upon the minimum opening existing between the two work rolls as they engage the strip. The roll opening is clearly a function of the separating force applied to the rolls, because all the elements that hold the rolls in place are elastic bodies, as are the rolls themselves. Consequently the roll opening must be affected by all the factors which enter into determination of forces, and by the stretch or deformation of the rolls themselves and all of the elements which influence their position. When the rolling speed is changed materially, the factors which are affected by speed change in turn, and the roll opening may become larger or smaller. Even if the entering thickness remains constant, the thickness of product from the single stand can be expected to reflect large changes in speed unless compensating adjustments are made in strip tension or in the position of housing screws. If the entering thickness varies, one can be certain that the thickness of product will be affected, even if speed remains constant. If entering thickness and speed vary concurrently, the problem becomes extremely complex, requiring much more knowledge than we now have to appraise the result.

Comparative evaluation of the factors which are affected by speed is impossible with the meager data now available. There is evidence to suggest that the coefficient of friction between material and rolls decreases with increasing speed, but the magnitude of this change under rolling mill conditions is unknown. Similarly, it has been suggested that the radial deformation of rolls in contact with strip or with each other diminishes at high rolling speed, but the extent of this effect has not yet been demonstrated. Tests have shown that the thickness of oil film in a sleeve-type bearing varies with speed, and this change can be calculated approximately if the load and oil viscosity are known; however, as the authors pointed out, the viscosity varies with oil temperature, which is itself a function of load and speed, so that accurate calculation of the change in film thickness becomes impossible even though the principles are well established.

In a five-stand tandem mill, the conditions encountered during acceleration or retardation are still more complex. Here the uncertainties outlined before are multiplied by five, and in addition we have the inevitable interrelation between thickness, speed relationships, and strip tension. The outstanding characteristic of the tandem mill in this connection is that all of its component parts are interrelated, so that a significant variation of any pertinent factor anywhere in the mill will be reflected by a corresponding variation of conditions elsewhere in the mill.

This paper provides only a limited appraisal of the situation, because too many factors remain unknown. A more accurate appraisal could be made if the strip thickness, strip tension, bearing load, speed, and screw adjustments were observed continuously and simultaneously at all five stands during retardation, slow speed operation and reacceleration. This, however, would be a costly procedure, difficult to justify with the anticipated value of the results.

Several detailed comments can be offered in connection with the reported observations. The authors mentioned the observed effect of roll eccentricity on bearing load, noting that the amplitude of the variations in bearing load decreases as the speed increases. They suggested that the decreased amplitude at high speed was apparent rather than real, and that the graphic meter was too slow in response to record the full amplitude at top speed. The fact is that this meter can record oscillations ranging from zero to full-scale deflection at a frequency of 30 cycles per second. The observations are accurate, in my opinion, and the decrease in amplitude at high speed reflects the greater effect of roll inertia.

The method employed by the authors to measure variations in oil film thickness, involving dial indicators mounted on the end covers and engaging the ends of the rolls, probably is less than adequate. The position of the ends of the rolls is affected by roll neck deflection, and unless the bearing chocks shift their positions to follow the deflection exactly, errors can be introduced which may be greater than the observed differences. Undoubtedly the thickness of oil film does change when the rolls are retarded from rolling to threading speed or reaccelerated to running speed; however, we do not yet have sufficient information, either theoretical or experimental, to state the magnitude of this change accurately.

The authors offer interesting suggestions of means to minimize the variation in oil film thickness. Their proposal to make the oil film as thin as possible implies that the bearing clearance might be reduced. This, we believe, is unwise, particularly in mills of the type under discussion which operate at high speed. Their suggestion to maintain constant oil temperature is valid in so far as it applies to the oil entering the bearings; in fact, this is done consistently in most mills. The point of concern, however, is the loaded region of the bearing, where the oil temperature is determined by the prevailing conditions of load and speed, and is not susceptible to external control.

The proposed application of high pressure lubricant to the loaded region of the bearing is not impossible; in fact, it has been done in certain instances to facilitate starting under load; however, it requires costly high-pressure pumps, and in addition is desperately difficult to apply in the manner proposed by the authors. In this arrangement, the thickness of oil film would be determined by the load, speed, bearing temperature, oil supply temperature, and the rate of oil supply. To maintain constant oil film thickness, it would be necessary to vary the rate of oil supply continuously to match the conditions of load, speed, and temperature prevailing at each instant. We suspect that this scheme is too difficult to be practical, but we will be glad to discuss it in greater detail with anyone who is genuinely interested.

The authors have dealt at much length with alleged variations in oil film thickness, whereas in my opinion, supported by study of the reported observations, the variations in strip tension and entering thickness are the chief culprits.

L. J. Gould: I am very pleased to get another curve showing horsepower on a skin mill or a tandem mill, because I am in the position that most of the chief engineers of the various steel organizations are in—that we are frequently asked how much can we speed a particular mill, after Mr. Stoltz, or his equivalent in other companies, has already set the limits.

The amazing thing to me is that the horsepower hours per ton at the various speed conditions apparently seem to be related only to reductions and not to that speed. I believe this warrants more investigation than it has had. The theoretical discussions of horsepower required for rolling, wind up with a series of formulae involving eight to ten constants. The numerical value of none of these is apparent, so that most of us go back and use a curve such as Mr. Stoltz has again produced, to try to guess what is going to happen next.

Unfortunately, from the standpoint of a theoretical solution, practically all our working rolls and back-up rolls are of such sizes that there is not sufficient variation of that factor to establish the effects of roll size which must be very important in the power required to roll, and particularly in the deflections which seem to be causing the trouble in overgage.

To anyone who has lived with a tin mill, it is nothing short of a miracle that anything comes out at that speed even approximating the dimension you intended it to be.

G. H. Rendel: The questions raised regarding oil film thickness and gage variations as a function of rolling speed should stimulate thinking and action along those lines.

With the increased speed available on cold rolling mills, the need arises to develop techniques and refinements which will permit utilizing that speed to obtain the maximum possible production consistent with a high quality product. Higher operating speeds necessitate faster rates of acceleration and deceleration. In fact, the more desirable rates of acceleration and deceleration are so rapid that an operator does not have sufficient time to make manual tension and screw adjustments to compensate for gage variations resulting from change in operating speed. On tandem cold reduction tin plate mills, during threading, accelerating and decelerating periods, the operators are quite busy operating valves and performing other unavoidable duties; therefore, any anticipated adjustments of controls during those periods should be avoided. We believe that manipulation of screws and tension controls to overcome gage variations during threading, accelerating and decelerating periods is an undesirable manner of operation. Furthermore, we contend that wherever practical automatic or inherent compensation should be incorporated in high speed mills to minimize off-gage production during these relatively short periods.

Rolling with relatively high interstand strip tension is highly desirable for the very good reasons outlined by the authors. A major portion of each coil is rolled at high speed; consequently in the interest of obtaining maximum benefits it is most important to employ relatively high tension when the mill is operating at full speed.

To utilize high interstand strip tension and maintain the margin of safety required for good rolling practice requires very close control of the mill drives. As an example suppose the regulation on one of the drive motors becomes slightly erratic, causing it to hunt, the resultant change in strip tension may cause strip break-

age particularly if the strip is brittle or if the edges are bad. We have observed instances where slight hunting of an intermediate drive motor would cause the finished gage to fluctuate, at regular intervals, more than 0.0015 in. When maximum permissible interstand strip tension is employed during full speed operation, any substantial increase in tension, to maintain gage, as the rolling speed decreases cannot be permitted without encountering excessive strip breakage.

With regard to the observed decrease in roll pressure as the mill slows down, in addition to the reasons pointed out by the authors it may be that the rate of deformation and the strip's resistance to compression at the higher speeds is a larger factor than is generally recognized and may well be one of the more influential factors.

The advantages of maintaining oil film of uniform thickness, to aid in obtaining on-gage products at the lower operating speeds is fully recognized; however, the maintenance of an oil film on the roll bearings for the purpose of eliminating the necessity of raising the screws to start the mill rolls may be of secondary importance principally because when satisfactory operations are obtained, the mills seldom come to rest with metal between the rolls. It would appear more logical to concentrate on eliminating the causes that make it necessary to start the mill from rest with metal between the rolls.

Because of the fact that overgage metal is produced at slow operating speeds, the most plausible correction for reducing the quantity of off-gage product is to thread, accelerate, and decelerate the mills rapidly and by using large coils. These features must be fully realized before delicate or fancy control devices for regulating gage at the lower speeds becomes attractive.

M. A. Leishman: We in our plant have investigated and measured back-up-bearing oil film thicknesses. We found that when our mill decelerated from 2800 down to 500 fpm that there was very little change in oil film thickness. From 500 fpm to Stop there was a change in oil film thickness of two mills to zero.

Some operators believe that the amount of off-gage due to this change in oil film thickness is not too important. But, I imagine there are many here this morning who have witnessed strip breakage when a mill starts from standstill, due to motors not all starting together. When a mill comes to a stand still with a heavy rolling pressure on it the oil film becomes zero and therefore journals and bearings "freeze."

Some stands will freeze worse than others depending on the roll pressure of each individual stand and then when a start is made the stand with the heaviest roll pressure will lag the others and a break is very likely to occur. If oil under high pressure was admitted between journals and bearings before a start was made this freezing action would be eliminated, "Strip Breaks" would be reduced and wear on bearings would be practically eliminated. To those of us who are familiar with the use of high oil pressure between bearings and journals on other heavy rotating pieces of apparatus, such as large motor-generator sets, it is only natural to expect the application of high oil pressure to back up bearings.

Manipulating screws of No. 1 and No. 2 stands in order to keep on gage we believe is good practice. Between stands No. 1 and No. 2 where strip is heavy and tension usually very high, ordinary screwdown operations do not affect tension to the point where looping and breaking might well occur. This does not hold true between stands No. 4 and No. 5. As an experiment we set up No. 5 stand so that ordinary screwdown operations on No. 5 stand would have little effect on tension between stands No. 4 and No. 5. Prior to this experiment, we had been operating our mill on a "constant feet per minute droop" basis. In order to make No. 5 motor sensitive to load change we set up a circuit to give it a "constant percentage speed droop." We chose a 15 per cent droop because this was the droop necessary at threading speeds. We did not know what would happen with this set up at the higher speeds but the results were amazing. Vicious screwdown applications at No. 1 and No. 2 stands would cause just the slightest bobble in tension between stands No. 4 and No. 5. On deceleration and acceleration we found that tension between stands No. 4 and No. 5 stayed almost constant. On tin plate schedules this meant that we were able to carry a very low tension between stands No. 4 and No. 5, a condition which our operators wanted. Besides this it relieved the operator at No. 5 stand of having to watch for hard metal and heavy sections.

H. W. Poole: Messrs. Stoltz and Brinks have done a fine job of analyzing some of the problems of cold rolling practices. Their efforts and results are certainly to be commended. However, for fear that we may get so close to the forest that we do not see the trees, I should like to mention a couple of associated problems.

The first is that in my opinion one of the major factors affecting the control of off-gage is the steel received from the hot strip mill. I am sure from Mr. Hitchcock's comments that he is inclined to agree. I believe that all of you know the importance of coming into the cold strip mill with good on-gage material. Papers on this subject were presented before the Association by Messrs. Mohler and Campbell some years ago. It is fortunate that we have today a better means of controlling the gage of strip rolled on the hot strip mill. I refer to the X-ray thickness gage as used on present day hot strip mills.

Secondly, I should like to mention Figure 5 as shown by Mr. Stoltz. There appeared to be a slight overshoot of voltage and some oscillation as the speed of No. 4 stand came from threading up to running speed. This oscillation appeared to have lasted as long as five or six seconds, although it was difficult to see it there. I am sure that Mr. Stoltz realizes that such oscillations in the mill speed can also cause off-gage material to be rolled.

Figure 16 illustrates the success which has been attained in bringing the new Jones and Laughlin 5-stand mill up to speed without such oscillations. At the bottom of the figure, the mill was started from rest and was then accelerated from threading speed to full running speed with practically no overshoot or oscillation. This record was made on a high-speed photoelectric recorder which is very fast.

Before concluding, I should like to say a few words in connection with Mr. Stoltz's summary. He mentioned the matter of trying to roll continuously on a tandem cold strip mill by welding the coils immediately

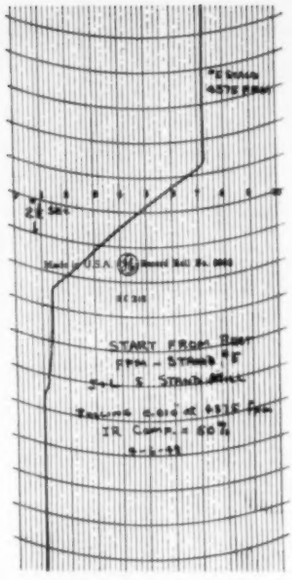


Figure 16 — Chart shows the acceleration of a five-stand tandem cold mill at the Aliquippa plant of the Jones and Laughlin Steel Corp.

ahead of the first stand. We have discussed the possibilities of doing this with several of the steel companies over the past few years and are still looking for a man with the courage to go ahead. Better welders have been developed and, I believe, that the day is here when the job can be done successfully. The problem is not too difficult when we realize that with a mill delivering strip at 4000 fpm, the entering speed is 500 fpm or less. The speed of the entering strip is thus no higher than that encountered in the pickling sections of several modern high-speed pickling lines wherein the coils are successfully welded. The quality of the welds has improved so much in recent years that the existing welds are frequently put through the tandem mill at top speed.

Probably the most difficult problem is to handle the strip as it comes out of the mill and most likely the mill would have to be slowed down to some extent. It will be necessary to have two winding reels with suitable shears and automatic guides for transferring from one reel to the other, but this is not new since it is now being done on moderate speed processing lines.

I again repeat that we would like to work on this problem with the man who has the courage to try it.

G. E. Stoltz: The discussion as presented has been very good. In some cases our data has been questioned, and in other instances the difficulties in solving some of the problems have been emphasized. We had hoped to make it clear that our tests had not been continued to the point where, in some instances, definite conclusions had been reached.

Mr. Klein has referred to problems of rolling at high speeds that are not covered in our paper. His point of view is all inclusive as would be expected from a man of his design and operating experience on mills of this type.

It is clear that Mr. Hitchcock has made quite a study of rolling flat products on strip mills. He refers to the results that might be obtained on a single stand mill with uniform gage entering the rolls during a period of speed change.

We participated in a test made under such conditions just previous to presentation of this paper but too late to include the data in this paper. Readings were taken on two coils, one being rolled to 0.0240 x 32⅛ in. and the other to 0.0236 x 32⅛ in. at 1440 fpm. During the last pass on each coil the mill was slowed during the middle of the coil, first to an intermediate and then to a threading speed with the following increase in strip thickness. No changes were made in the screw position or strip tension. The following observations were made:

Coil No. 1

Fpm	1440	800	300
Strip thickness, in.	0.0240	0.0248	0.0263
Per cent strip thickness	100	103.3	109.5

Coil No. 2

Fpm	1440	800	240
Strip thickness, in.	0.0236	0.0243	0.0265
Per cent strip thickness	100.0	103.0	112.2

On this same single stand mill it was observed from dial gages on the roll neck extension that there was a total change of 9 mils as the mill speed was decreased from 1440 to 300 fpm. It has been assumed that this was largely due to the decrease in back-up bearing oil film thickness. Practically the same results were obtained whether the mill was rolling steel or operating with normal roll pressure but with no steel in the rolls. This seems to eliminate the possibility of the rolled product influencing this particular phenomenon.

It is probable that there are quite a number of factors which affect gage with change of speed, but it is possible that only two or three of them are of any great consequence. If the effect of any factor of some importance can be offset by some practical means, the amount of overgage obtained at slow speeds would be reduced with consequent tendency to limit increased strip tension.

The small increase in strip tension between stands 3-4 and 4-5 as shown in Figure 5 over that of Figure 4 indicates what can be accomplished by screw movement of No. 1 stand without understanding all of the factors that normally cause overgage at slow speeds.

It is our understanding that the roll pressure meter has a flat response to five cycles per second, and a decreased response at higher frequencies.

We recognize there will be problems in supplying external means to force oil into the loaded region of a back-up bearing, but how difficult this solution will be will not be known until an application is made. The logical place to make such an installation is on a single stand mill.

Mr. Gould raises the question as to how the power to roll steel varies with speed. We have not studied this problem sufficiently to evaluate the various factors that affect the power required to roll steel. Curves similar to the one shown in this paper are obtained on mills of a given class and their use is confined to mills having the same characteristics.

We are in agreement with Mr. Rendel that any adjustment required to maintain normal gage or tension during periods of changing speeds should preferably be automatic. The amount of overgage should be consistent

so that it would lend itself to some practical method of correction.

In Mr. Poole's discussion he refers to a rise of voltage above normal when the mill is brought up to speed. This was due to overtravel of the generator rheostat which has been corrected. Since this is a common bus mill, all motors would be affected alike. Also at this high speed, any small change in speed would have little or no affect on gage as overgage begins to occur at much lower speeds.

Frank Dahlstrom: The paper is a major contribution by the staff of one of our great electrical manufacturing concerns in helping us to advance the strip rolling art. Therefore, we may well consider seriously the following statement from the paper: "This may indicate that we have reached the ultimate in speed, or that we have come to the place where a study should be made if further increase in tonnage is to be obtained."

This recalls to mind an extremely interesting paper which was presented by Mr. Biggert at a Youngstown, Ohio meeting of the American Society of Mechanical Engineers, November 10, 1927. At the beginning Mr. Biggert has stated: "Until somewhat over a year ago, progress in the rolling of strip steel had practically come to a standstill." . . . "If wider material was to be rolled, it was evident that fundamental changes in mill construction must be made, since increasing roll diameters with the inevitable increase in neck friction which they imply, had about reached the practical limit. The use of roller bearings was naturally considered but no bearing could be designed which would support the required load and be small enough to assemble in the 2-high mills then in use." The paper then describes some of the earlier 4-high installations.

We are again at the crossroads — it again appears that "progress in the rolling of strip steel has practically come to a standstill."

The lack of study, or more correctly, the lack of application of known principles has caused an economic loss to the industry of many millions of dollars.

One has only to recall the many arguments between the hot and cold roll strip personnel regarding "crown" to realize that mill progress in this respect has been substantially zero. To be sure — tension between stands, or between stands and coiling devices, are helpful but the foregoing remark refers to the mill only.

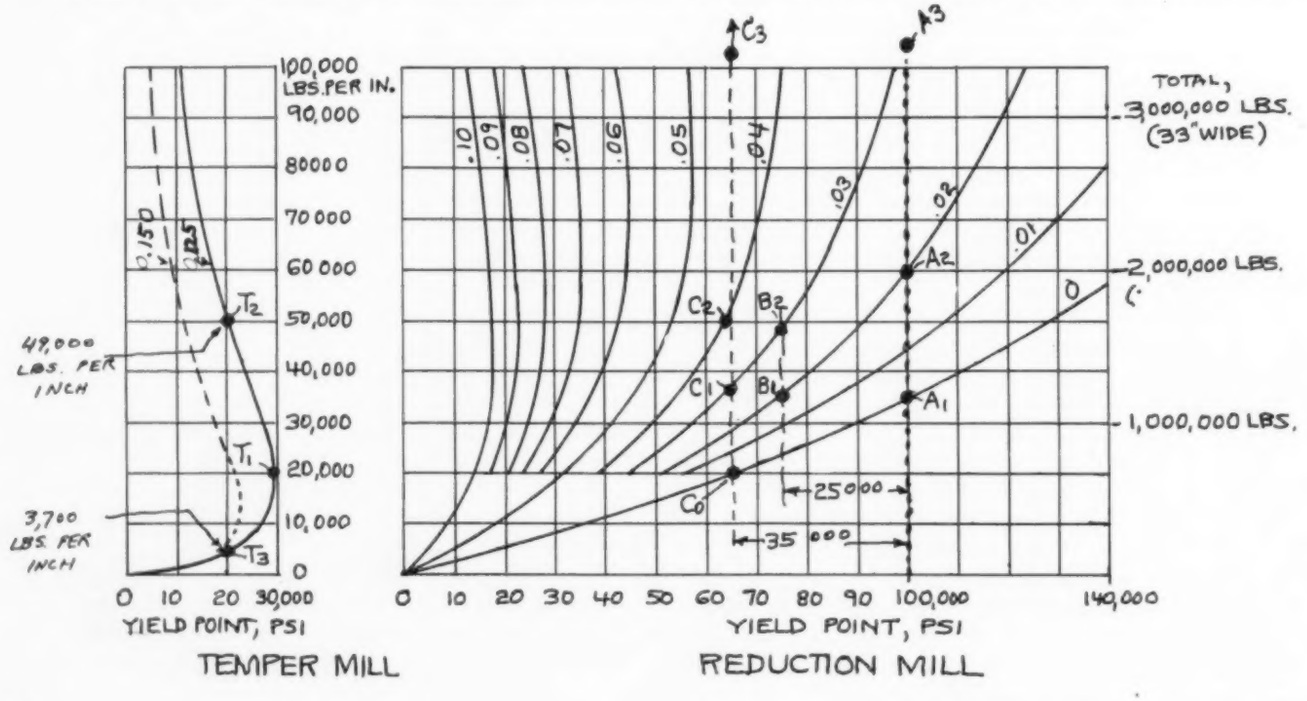
One mill builder states, "An interesting development in regard to working roll diameters is that it has no appreciable effect upon the power consumption of the mills. This is of course, contrary to all previous conceptions, but tests over a wide range of diameters have shown that for like reductions — the power per ton is almost exactly constant."

OFF-GAGE STRIP — REVIEW OF COMMENTS

The condition of "off-gage" strip has been discussed many times.

From a previous paper "Gage Control for Cold Strip Mills" by F. Mohler in the 1939, Proceedings of the Association of Iron and Steel Engineers, the following pertinent remarks are abstracted. "It is an observed fact, and proven by actual experience that if a mill is set up to be on gage at a certain speed, and if the screw settings, cooling solution, lubrication, etc. are left fixed the gage will become heavy if the speed is decrease and light if increased"... "Also, it is common knowledge that more reduction can be obtained with roll lubrication, and that quantitively one is a function of the other. It is conceivable therefore that the lubrication film may have some relation to speed. It has been definitely established in connection with tests on oil lubricated sleeve bearings that the thickness of the oil film

Figure 17 — The charts show the relation between the effective yield point and rolling pressure. The curves in the left chart have been derived for a temper mill, and the ones on the right have been derived for a cold reduction mill.



increases with speed. If this were true in connection with a lubricated roll, it would mean that greater reductions would be obtained at high speed than at low speed. The same phenomena applies to the oil film bearings with the same ultimate result."

Professor Trinks has also pointed out in a paper presented at the May 1948 meeting of the American Iron and Steel Institute that: "The great resistance of the strip causes flattening of the rolls. The flattening increases the contact length, whereby in turn, the roll separating force is increased at a much higher rate than the contact area. In spite of the fact that the lubricant is not burnt up, pressures build up enormously, often exceeding 200,000 psi. During acceleration at the beginning and during retardation at the end of rolling a coil, the rolling speed is smaller than it is during the rest of the time. In consequence, more time is available for squeezing out the lubricant, skin friction grows, the rolls flatten more, and a higher roll pressure would be needed to produce the same reduction as is obtained at higher speed."

The question is: "What can we do about it, and the basic method of solving this problem is the same as for any other problem. I can find no better way to express the thought than to quote: "The problem was attacked first by a theoretical analysis, and second by some controlled experiments to test some of the implications of the theory."

RELATION OF TENSION AND PASS FRICTION TO REQUIRED ROLLING PRESSURE — NO. 5 STAND

Figure 17 is a chart showing the relation between "effective" yield point and rolling pressure — for coefficients of pass friction varying from 0 to 0.1 — for a reduction and strip thickness which is typical of No. 5 stand. The curves are based upon computations made by the writer.

In the middle of the chart there is a scale for rolling pressure in lb per inch of width, ranging from 0 to 100,000 lb. At the right of the chart the scale shows the corresponding total rolling load in lb for a strip 33⅓ in. wide. The scale at the bottom refers to the yield point of the strip.

We have assumed the yield point of the strip as it is reduced in say, stand No. 5 to be 100,000 psi. Points A_1, A_2 and A_3 refer to the strip in this condition.

Points B_1 and B_2 refer to a strip having a yield point of 75,000 psi. It is assumed that a strip having an initial yield of 100,000 psi and stressed by tension to a value of 25,000 psi, acts the same in the mill as an unstressed strip having a yield of 75,000 psi. Whether or not a tensile stress of 25,000 psi is the exact value is not materially important.

What is meant is, that strip having an initial yield of 100,000 psi is tension stressed to such a value that the figure 75,000 psi, can be used to calculate the rolling pressure. In other words, we can say that the stressed material has an "effective" yield point of 75,000 psi.

Similarly — points C_0, C_1 and C_2 refer to a strip which has been tension stressed at a value of approximately 35,000, which results in an "effective" yield point, 65,000 psi.

In order to see the problem we will first determine the required rolling pressure which must be exerted in No. 5 stand in order to maintain gage.

The eleven curves in the chart show the relation between required rolling pressure and effective yield point for average coefficients of friction between strip and rolls, varying from 0 to 0.10, by steps of 0.01.

The curve at the extreme right is for a perfect condition, that is, there is no friction between the rolls and strip. Point A_1 shows that for these ideal conditions, there would be required a rolling pressure of 35,000 lb per inch of strip width (or substantially 1,200,000 lb total) in order to reduce the strip to the required amount.

As a result of two years study, and many calculations and analysis of test data which have been made, we can reasonably estimate the coefficient of pass friction to be 0.02 for No. 5 stand when running at its optimum speed. Reference to Figure 11 in the Stoltz and Brinks paper shows the optimum speed to be in the vicinity of 2500 fpm for the tests reported. It appears evident that at speeds above 2500 fpm the pass was not supplied adequately with lubricant, otherwise the gage would not have increased but would have decreased.

Referring again to Figure 17 — for a coefficient of pass friction, 0.02, and with no tension, the rolling load for a yield point of 100,000 psi would be 60,000 lb per in. (or 2,000,000 lb total) as shown by point A_2.

In actual rolling practice an appreciable tension stress would be exerted on the strip — and if we assume 25,000 psi tension stress — or 75,000 psi "effective" yield, then the rolling load would be 35,000 lb per inch (1,200,000 lb total) as shown by points B_1.

If the strip speed is now reduced — the coefficient of pass friction will increase, and if it increases by only 0.01 we then have the conditions as shown by the next curve to the left marked 0.03. If the tension stress is not changed, we first find from curve 0.03 that the rolling pressure must now be increased to B_2 which corresponds to 48,000 lb per inch (1,600,000 lb total).

It is hard to alter the rolling pressure in response to rolling mill requirements. The other alternative is to still further increase the tension as this can be easily and quickly done, thanks to the flexibility of electrical control methods.

In actual rolling mill practice, the tension stress would be increased to say 35,000 psi — which causes the strip to have an "effective" yield point of 65,000 psi. The operating point is now C_1 and the rolling pressure is now the same as at the higher speed "B." We have now reached the practical limit to which the strip can be stressed by tension, as excessive strip breakage would occur if this stress is increased at this point in the mill.

If the mill is now slowed down further and the pass friction thereby increased to say 0.04 we must increase the rolling pressure to point C_2 — or 50,000 lb per inch of strip width in order to maintain gage. As pointed out, this is hard to do with the mills as now constructed. Furthermore, there is no object in doing this as the effect would be only temporary, because further decrease in speed would call for more pressure. In the region between curves 0.04 and 0.05 the required pressure would be infinity — as shown by C_3. Therefore at speeds corresponding to a coefficient of friction less than 0.03, the mill rolls will be forced apart.

There is no remedy for this and over gage material

would be produced. To follow down the line would now require additional charts, since the chart, as drawn, is for uniform gage.

Figure 17 shows us that the combination of a large roll and thin strip — 21 in. to 0.010, (or 2000 to 1 approximately) is very sensitive to pass friction, therefore we must know the coefficient quite accurately in order to predict the performance of such a combination.

FORCES IN TEMPER ROLLING

In the concluding remarks of a paper, published in the June 1950, *Iron and Steel Engineer*, "Electric Equipment for High Speed 2-stand Temper Mills," R. E. Marrs has written:

"In this brief description of the electric equipment for a typical high speed 2-stand temper mill, several references have been made to the differences of opinion regarding operating requirements. When this difference exists, it is most difficult to select machine ratings that will be satisfactory to both mill operators and equipment builders. It is hoped that this paper will help unify these conflicting opinions."

We believe that until a complete analysis is made of what is going on in the pass of a temper mill, there will be marked differences of opinion on the design and operation of the mill. In addition, the full possibilities of the mill cannot be realized until we have a more complete fundamental understanding.

This statement will be partially clarified by the following: The curve 0.125 on the left side of Figure 17 shows the relation between yield point and lb per inch of strip width for a conventional temper pass, with 18 in. diam rolls.

We will assume the yield point of the strip to be 50,000 psi. If we tension stress the strip to, say, 21,000 psi (or any other more exact value which will result in an "effective" yield of 29,000 psi), we will then be operating at a condition shown by point T_1 where the rolling pressure is 20,000 lb per in. strip width.

If we now increase the tension stress by substantially 10,000 psi and thereby reduce the "effective" yield to 20,000 psi, we find that two points of operation are possible, T_2 and T_3.

The point T_2 corresponds to 49,000 lb per inch of strip width and is not very far "off" from conventional practice, which varies from T_2 to T_1.

The curve shows that if we increase tension, we must also increase the rolling pressure. This seems to be inconsistent with our conventional conceptions. However, we also note from the chart that if we increase the coefficient of pass friction from 0.125 (full line) to 0.15 (dotted line) the required rolling pressure is less. This is more consistent, as sand blasting of rolls is often done in order to effect the required reduction to the dry strip.

Why do we not operate at T_3 — where the required rolling pressure is only 3700 lb per inch of strip width?

The writer has worked on this problem and, as a result, has developed a mill, which is a dwarf, compared to the conventional temper mill. This mill is calculated to operate at 2000 to 3000 lb per in. of strip width, with low strip tension stresses — say not over 5000 psi.

Since the main object of this discussion is not to study the temper mill, but is primarily to show what intensive study will do to determine fundamental principles — it will be sufficient to state that the diagram, is one of very many which has been made for rolls varying from 5 to 24 in. diam, for different reductions, percentages of crown, coefficients of friction, etc.

Referring to Figure 17, if we take a section through all curves along the vertical line 100,000 psi, and plot the results we obtain curve (100,000 psi) shown on left in Figure 18. In like manner we can obtain similar curves 75,000 and 65,000 psi. It will be noted again that the rolling pressure is very sensitive to the coefficient of friction.

For example, consider points C_o, C_1 and C_2, Figure 17, where tension stress is assumed to be 35,000 psi which results in an effective yield point 65,000 psi. If the coefficient of pass friction could be 0, then the required rolling pressure would be 18,000 lb per inch — as shown in C_o in Figure 17, and this point is accordingly noted as the start of curve 65,000 Figure 18. If the coefficients of pass friction are 0.03 and 0.04, then the corresponding lb per inch would be 35,000 and 50,000 as shown by points C_1 and C_2 Figure 17. These same readings are duplicated by similar points C_1 and C_2 in Figure 18.

If the pass coefficient of friction should now be increased by only 0.005 (or ½ of 1 per cent) then the required rolling pressure would be infinity — see point C_3 in Figure 17. In other words, we now have the condition where we "roll the roll," as many mill operators have described it. Point C_3 is also noted in Figure 18.

UPPER AND LOWER ROLL LOAD DIVISION

If we assume that the lower surface of a strip is not as well lubricated as the top surface, we could easily have the condition where the pass coefficient of friction would be 0.04 between the bottom roll and strip and 0.03 between the top roll and strip.

From curve, 65,000 psi of Figure 18, we find that the required roll pressure would be 50,000 lb per inch on the bottom and 35,000 lb per inch on the top. Since the top and bottom pressures must be alike, and since we know it is easier to obtain a required reduction when the friction is reduced by better lubrication, it follows that the top roll must make the larger reduction. We can show this by analyzing further.

We can assume an average of 50,000 and 35,000, or 42,000 lb per inch available to obtain a given reduction. With 0.04 coefficient of friction for the bottom roll, we will require 50,000 lb as stated; but since we now have only 42,000 lb available, we may assume (for demonstration purposes) that the actual reduction will be $\frac{42,000}{45,000}$ of its half share, or 42/45 x 50 per cent or 40 per cent of the total.

Since it only requires 35,000 lb per inch of width for the top roll to do its half share at 0.03 coefficient of friction, and since we have 42,000 available, we will then be able to do 42/35, or 1.2 x 50 per cent or 60 per cent of the total with the top roll. The load on the top roll will, therefore, be 60/40, or 1½ times that of the lower roll. (If the pass coefficients should be 0.04 and 0.045, then one roll would do all the work!)

Electrical engineers have developed various means of "load balancing" control to cope with this condition. What is also urgently needed is "lubrication balance" control.

About a year ago, I tried to analyze the conditions as best I could at the time, and a pass coefficient of 0.03 seemed to be nearest for the conditions as I understood them.

OFF-GAGE STRIP — RELATION OF CHANGES OF SPEED TO ROLL PRESSURE REQUIREMENTS

In the right side of Figure 18 the two solid lines which enclose the cross-hatched area are tentative values of pass coefficient of friction for speeds varying from 0 to 5000 fpm. The lower line represents, what I believe to be, the best practice obtainable at present; the upper line represents, perhaps, the relation when conditions are not up to standard, and it is entirely possible that the changes in lubrication efficiency are such that conditions momentarily change between limits shown by the upper and lower lines (thus upsetting load balance).

Between the two solid lines is a dot and dash line which is more in accord with the tests reported in the Stoltz and Brinks paper, as shown by Figure 11, 12 and 13, since it appears that there was a deficiency of lubricant at the higher speeds.

At a speed of 5000 fpm the assumed coefficient of pass friction is 0.03 (dot and dash lines). For a tension stress of substantially 25,000 psi (or an effective yield of 75,000 psi) the rolling load for 0.03 coef = 45,000 lb per inch — point b_1 left side of Figure 18. The point b_1 is also indicated on the right curve.

At 3500 fpm, the pass coefficient of friction is 0.028, which corresponds to 41,000 lb per inch.

At a speed of 2500 fpm, the pass coefficient of friction is again 0.03 — and the resultant rolling load will be 45,000 lb per inch (point b_3).

At a speed of 2000 fpm, the coefficient is 0.035, which would result in a rolling load of 57,000 lb per inch (see b_4) which would cause the gage to increase appreciably.

However, by this time the tension would have been increased to a value such that the "effective" yield might have been decreased to a 70,000 psi. Using curve between 75,000 and 65,000 we find that a coefficient of friction 0.035 corresponds to a value of 46,000 lb per inch (point b_5), which maintains gage.

At a speed of 1500 fpm, the coefficient of friction would be 0.04 — and if the "effective yield point is further reduced by tension to 65,000, the rolling pressure would be 50,000 lb per inch (point b_6).

From now on no further decrease in yield point is possible as the strip is tension stressed up to its safe limit.

At a speed of 1200 fpm, the coefficient = 0.045 and the resulting rolling load would be infinity — see C_3. This point is also indicated by b_7, Figure 18. Therefore, it is impossible to maintain the original gage at speeds of 1200 fpm, or less.

The next step is to compare the dotted curve which connects points — b_1, b_2, b_3, b_5, b_6 and b_7, with the curves in Figures 11, 12 and 13. The discrepancy between the two curves is to be expected, since the dotted line, Figure 18, is for the condition of constant gage.

It will bear repeating that Figure 18 shows us that it is impossible to maintain gage below 1200 fpm — and in that respect the agreement between the dotted curve and Figures 11, 12 and 13 is reasonably close.

ENERGY — CONSUMPTION

Reports that the hp-hr per ton required to obtain a given reduction are the same on the high speed mills as with the lower speed mills were as hard for the writer to believe as is also the statement that the energy per ton is the same on the sendzimir as it is for mills with larger work rolls.

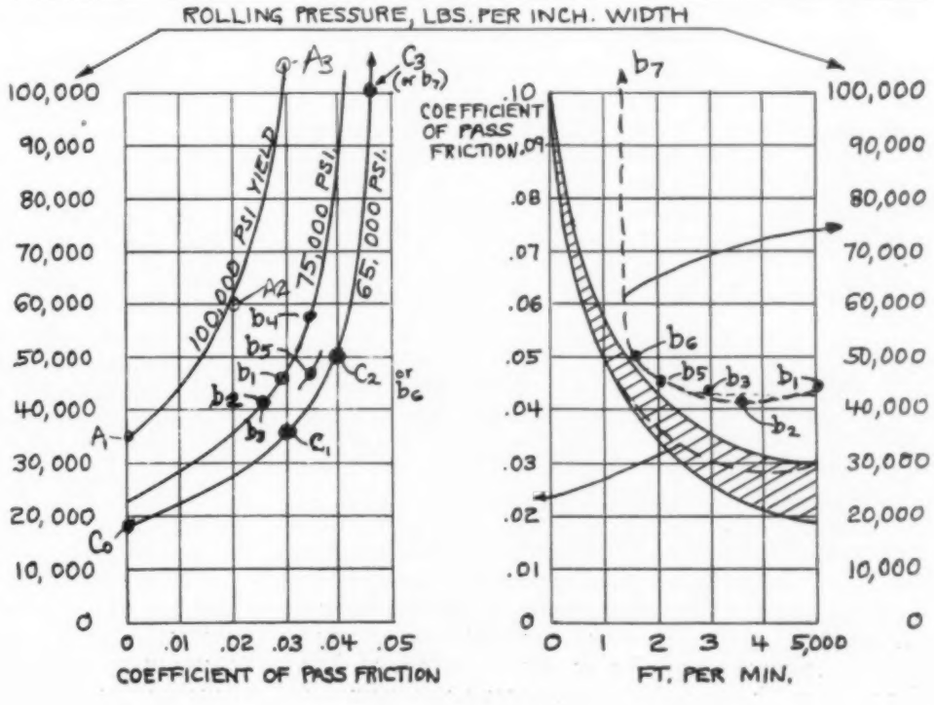


Figure 18 — The curve on the left shows the effect of coefficient of friction on the rolling pressure. It is noted that the pressure is very sensitive to changes in the coefficient of friction. The chart on the right gives the coefficient of friction for various speeds.

After careful tests with a small sendzimir mill, I found that one-third of the power supplied to the mill was lost in the intermediate rolls and roller bearing units; that is, only two-thirds of the power actually reached the work rolls.

Considering now the high-speed multi-stand mill, the lower coefficient of pass friction with increase in speed should result in less energy at high speeds. To offset this we know that the power lost in oil film bearing friction should vary substantially as the square of the speed, provided the viscosity and dimension of the oil film remains unchanged.

If the viscosity is reduced approximately 20 degrees F each time the speed is doubled, then the bearing loss would vary directly as the speed, and the overall energy bearing loss, per ton, would be substantially constant. When discussing this question with Mr. Brinks, one sheet of test data was found which showed that the losses in the mill — without strip — seemed to vary directly with the speed of the mill.

These few brief comments are given to show that several factors must be evaluated if we wish to have a basic picture of the fundamentals relating to energy consumption.

BEARING OIL FILM THICKNESS

The inspiration for the oil film roll neck bearing was a paper by George Karelitz "Oil Ring Bearings" published in the ASME Transactions in 1930.

After the writer had made many pages of calculations (based upon the Karelitz paper) taking into consideration minimum oil film thickness, various viscosities, effects of speed, clearance, oil flow, etc., a 10 in. experimental roll installation was constructed for shop tests, and later a larger one, for field tests.

The tests confirmed the calculations. Here again, the results of fundamental study were confirmed by subsequent events. Using the same methods as were used for the pioneer designs, the sum of both top and bottom oil film thicknesses for the bearings in the Weirton mill should be 0.005 in. at 5000 fpm or about 0.002 in. at 1000 fpm.

When we consider the relatively enormous changes in rolling pressures which would be required to maintain gage, it is evident that the change in oil film thickness is a minor cause of "off-gage" strip. Changes in gage are also reported in connection with the use of roller bearings, where mill speed conditions are similar.

In Figure 19, the lower curve in the upper left chart shows the required rolling pressures at 5000 fpm for all stands, using pass reductions derived from the Stoltz and Brinks paper Figure 3. In general, they are about 20 per cent higher than those reported. If the actual hardness of the strip after each stand had been given, the calculated results should not have been "off" more than plus or minus 10 per cent or less.

The upper full line curve shows the rolling pressures that would be required at 500 fpm if the tension values were unchanged (i.e. — as shown in full lines, in the chart below). If the tension stresses in stands 3-4-5 are increased to 35,000 psi (dotted line) then the required rolling pressures would be as shown in dotted line above. It will be seen that it is impossible to maintain gage in stands 4 and 5 when the mill is slowed down to 500 fpm.

The upper right chart of Figure 19 shows the rolling loads at 5000 fpm and at 500 fpm. At 5000 fpm, the load on stand No. 3 is reduced by 20 per cent on stand No. 4 by 33 per cent, and on stand No. 5 by 50 per cent. The tension, stand No. 3, is unchanged (25,000 psi) while the tensions, stands 4 and 5 are less, 27,000 and 25,000 psi.

At 500 fpm threading speed, the rolling pressures are within reason, especially if the tension stresses are again increased to 35,000 psi (dotted curve lower right). In this case the rolling pressure will be only 1,900,000 lb on Stand 3, 1,750,000 lb on Stand 4, and 1,100,000 lb on Stand 5, as shown by the dotted line.

The upper right curve shows us that we can maintain gage if the roll diameters are reduced in stands 3, 4 and 5. However, such a mill will be more sensitive to differential temperature changes, which in turn, will require substantially large tension values in order to obtain flat strip.

The chief reasons for gage variations in stands 4 and 5 are not due to high speeds, but are due to large rolls and thin gages.

Much more study will be required of the entire process in order to predict the best mill proportions.

SUMMARY

As a result of much study to determine "what is going on" in the pass, the following comments are offered for consideration.

When we increase the size of a strip mill stand, we increase the pressure requirements, which requires a still larger mill, which increases the pressure, and so on — and in the case of thin materials we have a real problem. The losses in an oil-film bearing increase with the size and rpm. The extremely large mills are hard to adjust, tend to cause large gage variations, unequal load division between top and bottom rolls, and require heavy strip tensions. They require rapid acceleration and retardation to cut down "off-gage" losses. In order to maintain gage, the change in friction conditions would require pressure requirements to change two to one — or more — depending upon the strip speed range, and the ability to compensate to a certain extent by tension control.

It appears that (at least) stands 4 and 5 in the tin plate mill should be scrapped also — and in both types of mills a new and quite different style of mill installed — which will not only maintain gage but will quickly control contour to compensate for differential roll temperature changes and changes in strip "crown." Such a mill would also allow smaller strip tension, and keep strip breakage to a minimum.

APPENDIX

The reader will no doubt question the validity of many of the charts and statements which have been presented in this discussion. For example, Figure 17 shows information about "skin passing" which is, perhaps, new to the reader.

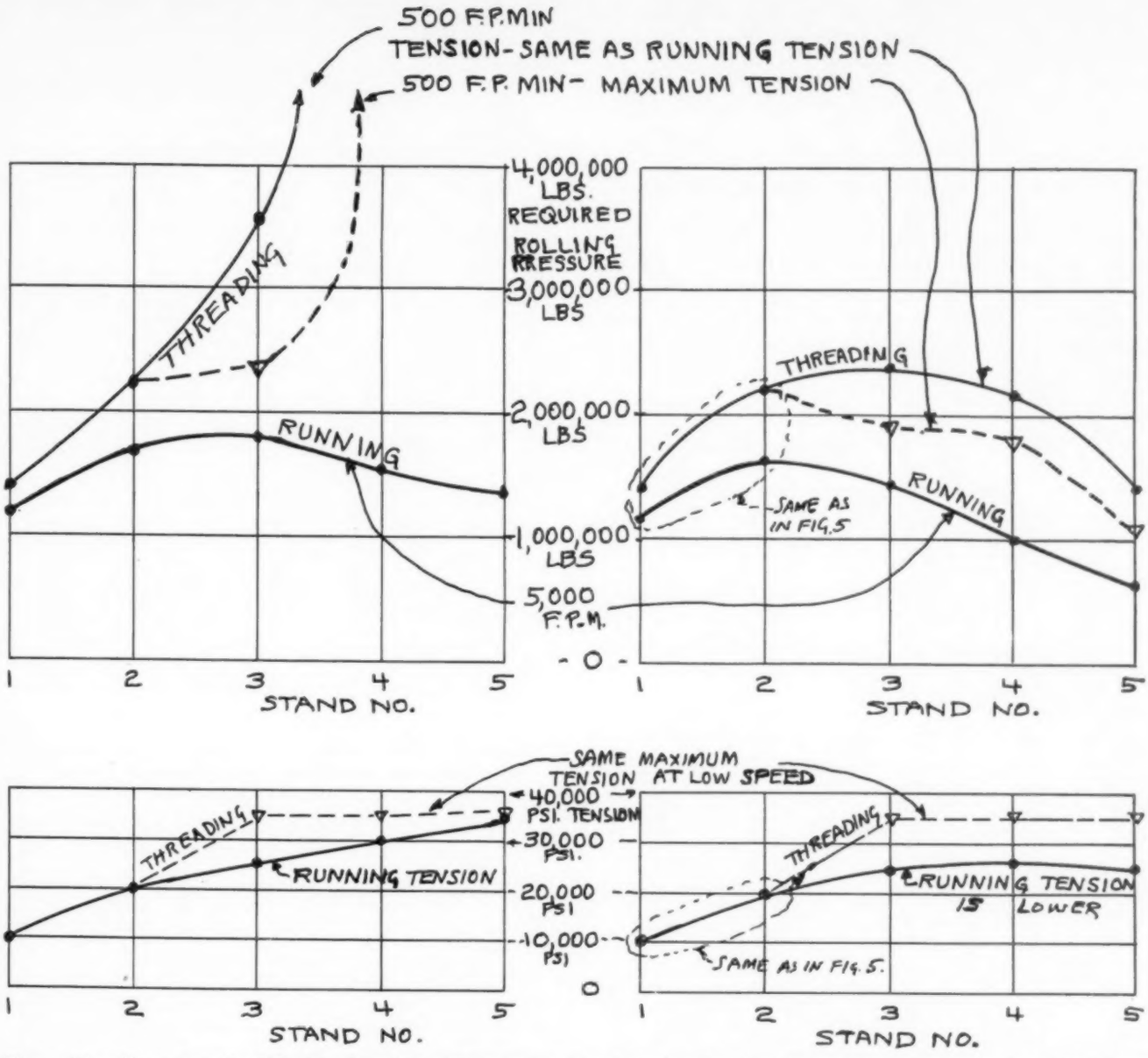


Figure 19 — Curves on the left side show the rolling pressure and tension required to maintain gage in present five-stand mills. The curves on the right show the lower pressures and tensions required if smaller rolls are used in the last three stands.

The basis of many of the charts can be traced to a curve in an AISE paper by Stone and Greenberger — "Rolling Pressures in Strip Mills," 1943 Proceedings, page 113, Figure 5.

It is well known in the art that the rolling pressure must be increased with increase in roll diameter, and with decrease in strip thickness; also that dry rolling requires more pressure than lubricated rolling.

In other words, the required rolling pressure depends upon the coefficient of pass friction, μ, times the arc length of contact, L, divided by the average strip thickness in the pass, T, or

$$\frac{\mu L}{T}$$

This relation is clearly shown by the curve in the Stone and Greenberger paper. This curve is reproduced in this discussion in Figure 20. The Stone and Greenberger paper states that "data which has been examined indicates that the pressure multiplication factor (at the left of the chart) can be applied to all flat rolling conditions to explain quantitively and with reasonable accuracy the spread between the constrained yield strength and the exhibited resistance to compression."

As a demonstration, we will now calculate the values for locating points T_2 and T_3 — Figure 17 using the curve, of Figure 20 together with other formulas well known to those who make such computations as part of their engineering practice.

We have assumed an 18-in. roll, reducing a dry strip from 0.010 to 0.0097, or 0.0003 in.

The contact length, (rigid roll basis) = 0.052.

$$\sqrt{9 \times 0.0003} = \sqrt{0.0027} = 0.052$$

The next step is to determine the so-called "true" contact length, which takes into account local roll flattening.

To do this we use a rather formidable looking equa-

tion derived by Hitchcock and reproduced on page 112 — Stone and Greenberger paper as follows:

$$L=\sqrt{R(T-t)+\left[\frac{8R(1-^2)P}{\pi E}\right]^2}+\frac{8R(1-\sigma^2)P}{\pi E}$$

Since the rolls are steel, having a radius R = 9 in. and T − t = 0.0003 in. — the above expression simplifies to

$$L=\sqrt{\left(\begin{matrix}\text{Rigid contact}\\ \text{length}\end{matrix}\right)+\left(\frac{P}{1{,}450{,}000}\right)^2}+\frac{P}{1{,}450{,}000}$$

P is the compressive stress actually offered by the strip as it is reduced in the pass, and is equal to the multiplication factor (MF in Figure 20) times the so-called "constrained" yield strength.

But, the multiplication factor depends upon $\frac{\mu L}{T}$ and we are trying to find L. Therefore we must assume a trial value for the multiplying factor and thus obtain a trial value of P. This can be done, as we know the constrained yield strength.

In Figure 17, the yield point for both points T_2 and T_3 is 20,000 lb per inch. Where strip elongates in one direction only, as in the rolling process, Nadai has shown that the "constrained" yield strength equals the conventional yield strength times 1.16.

For Figure 17, the constrained yield strength, for points T_2 and T_3 = 1.16 x 20,000, or, 23,200 psi.

Having access to the complete data for all charts, we can, at once, correctly assume for p, (or actual compressive resistance offered by the pass) the following values:

For point T_2, 185,000 psi — which is 8 times the constrained yield strength. This shows us the penalty we have often paid when "skin pass rolling."

For point T_3, we will assume 42,000 psi — which is only 1.82 times the constrained yield strength.

The assumed values for MF — Figure 20 are then

8.0 for point T_2 Figure 17
1.82 for point T_3 Figure 17

We will next determine L, so that we can then calculate $\frac{\mu L}{T}$. From the curve Figure 20, we can check and find out if our assumed values of MF are correct.

For T_2 Figure 17 where p = 185,000 psi

$$L=\sqrt{(0.052)^2+\frac{185{,}000}{1{,}450{,}000}}+\frac{185{,}000}{1{,}450{,}000}$$

$$=\sqrt{0.052^2+0.128^2}+0.128$$

$$=\sqrt{0.0027+0.0164}+0.128$$

$$=\sqrt{0.0191}+0.128=0.138+0.128=0.266 \text{ in.}$$

Since $\mu = 0.125$ (See Figure 17)

then $\frac{\mu L}{T}=\frac{0.125 \text{ x } 0.266}{0.010}=3.32$

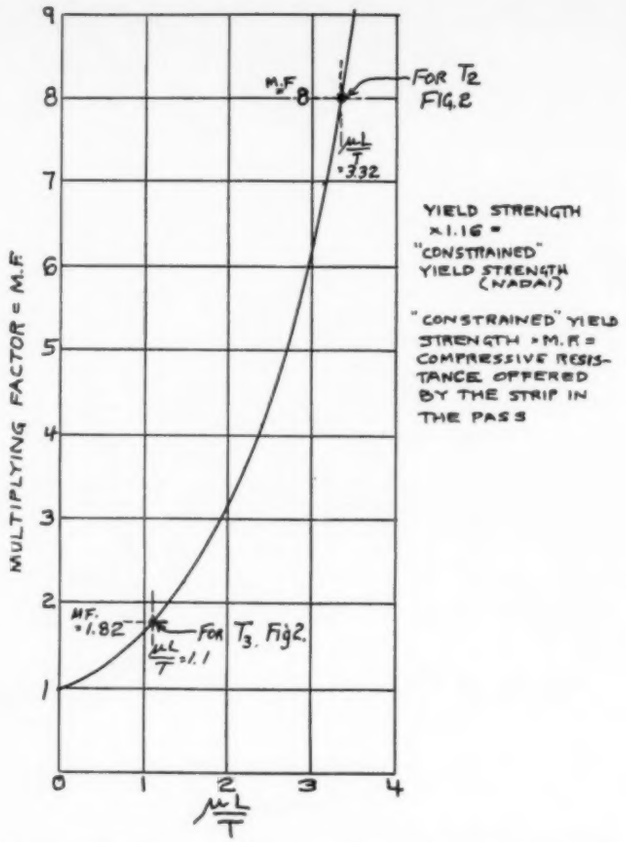

MULTIPLYING FACTOR = M.F
M.F = 8
FOR T_2 FIG. 2
$\frac{\mu L}{T}$ = 3.32
YIELD STRENGTH x 1.16 = "CONSTRAINED" YIELD STRENGTH (NADAI)
"CONSTRAINED" YIELD STRENGTH x M.F = COMPRESSIVE RESISTANCE OFFERED BY THE STRIP IN THE PASS
M.F. = 1.82
FOR T_3 Fig 2.
$\frac{\mu L}{T}$ = 1.1
$\frac{\mu L}{T}$

Figure 20 — This curve was developed by Stone and Greenberger and shows the relation of friction, arc length of contact, and thickness to the required rolling pressure.

From the curve, Figure 20 we find that when $\frac{\mu L}{T}$ = 3.32, then the multiplying factor = 8.

This is what we assumed, having previously done all the trial and error work. The rolling pressures would be 0.266 x 185,000 = 49,000 lb per inch of width. This corresponds with T_2, Figure 17.

For point T_3, Figure 17, where assumed value of P = 42,000 psi

$$L=\sqrt{(0.052)^2+\frac{42{,}000}{14{,}450{,}000}}+\frac{42{,}000}{14{,}450{,}000}$$

$$=\sqrt{(0.052)^2+(0.029)^2}+0.029$$

$$=\sqrt{0.0027+0.00084}+0.029$$

$$=\sqrt{0.00354}+0.029=0.059+0.029=0.088=L$$

$$\frac{\mu L}{T}=\frac{0.125 \text{ x } 0.088}{0.01}=1.1$$

From curve, Figure 20, MF = 1.82, which is also what we assumed. The rolling pressure would be 0.088 x 42,000 = 3700 lb per inch of width. This corresponds with T_3 — Figure 17. These examples are only two, of many hundreds which have been made in order to completely study "temper passing." For cold rolling, many more must be made — and a complete picture of the temper and reduction mill principles and their applications would require a volume.

CURRENT AISE DISTRICT SECTION MEETINGS

BIRMINGHAM SECTION

Monday, October 30, 1950 — Dinner 6:30 P.M.; Meeting 8:00 P.M.

"Materials Handling in the Steel Industry," by L. O. Millard, Assistant General Sales Manager in Charge of Engineering Sales, Link Belt Co., Chicago, Ill.

Thomas Jefferson Hotel, Birmingham, Ala.

BUFFALO SECTION

Tuesday, November 14, 1950 — Dinner 6:30 P.M.; Meeting 8:00 P.M.

"Properties and Application of Ductile Iron," by G. L. Cox, Manager, Empire State Section, International Nickel Co., Rochester, N. Y.

Sheraton Hotel, 715 Delaware Ave., Buffalo, N. Y.

CHICAGO SECTION

Wednesday, November 8, 1950 — Dinner 6:15 P.M.; Meeting 7:45 P.M.

"New Developments in Steel Mill Equipment," by C. A. Scarlott, Manager of Engineering Publications, Westinghouse Electric Corp., Pittsburgh, Pa.

Phil Smidt's Restaurant, 1205 North Calumet Ave., Hammond, Ind.

CLEVELAND SECTION

Monday, November 20, 1950 at Cleveland, Ohio — Dinner 6:30 P.M.; Meeting 8:00 P.M.

Tuesday, November 21, 1950 at Youngstown, Ohio — Dinner 6:30 P.M.; Meeting 8:00 P.M.

"Erection of Ore Bridges, Unloaders, and Conveyers," by R. C. McDowell, President, McDowell, Inc., Cleveland, Ohio.

Cleveland: Cleveland Engineering Society, 2136 E. 19th St., Cleveland, Ohio.

Youngstown: El Rio Club, Youngstown-Warren Rd., Route 422, Youngstown, Ohio.

DETROIT SECTION

Tuesday, November 14, 1950 — Dinner 6:30 P.M.; Meeting 8:00 P.M.

"Blast Furnace Controlled Split Wind Blowing at Algoma" by W. O. Bishop, Technical Assistant, Algoma Steel Corp., Ltd., Sault Ste. Marie, Ontario, Canada

"Rebuilding of Inner Wall [Lining] of No. 5 Blast Furnace at Algoma" by Douglas Joyce, Assistant Blast Furnace Superintendent, Algoma Steel Corp., Ltd., Sault Ste. Marie, Ontario, Canada.

Dearborn Inn, Oakwood Boulevard, Dearborn, Mich.

PHILADELPHIA SECTION

Saturday, November 4, 1950 — Dinner 6:00 P.M.; Meeting 7:00 P.M.

"Automatic Control Systems for Multi-Fuel Firing of Boilers, Open Hearth and Reheating Furnaces," by R. L. Willis, Assistant Combustion Engineer, Bethlehem Steel Co., Bethlehem, Pa.

'Operation and Maintenance of Electronically Operated Instrument Equipment," by John R. Green, Manager of Steel Division, Minneapolis-Honeywell Regulator Co., Industrial Division, Philadelphia, Pa.

Engineers' Club, 1317 Spruce St., Philadelphia, Pa.

PITTSBURGH SECTION

Wednesday, November 1, 1950

INSPECTION TRIP (with Cleveland District Section) through Midland, Pa. Works of Crucible Steel Co. of America. Members will assemble at 10th St. plant gate at 1:00 P.M. There is no paper or dinner after the trip.

Monday, November 13, 1950 — Dinner 7:00 P.M.; Meeting 8:00 P.M.

CRANE SYMPOSIUM

"Late Developments in Soaking Pit Crane Design," by Robert W. Harry, Vice President, Alliance Machine Co., Alliance, Ohio.

"Late Developments in Open Hearth Charging Machines," by Harvey W. Ball, Assistant Chief Engineer, Morgan Engineering Co., Alliance, Ohio.

"Spring End Trucks on Steel Mill Cranes," by Hugh K. Hybarger, Executive Engineer, Shaw Box Crane & Hoist Division, Manning, Maxwell & Moore, Inc., Muskegon, Mich.

"Crane Limit Switch Failures," by C. H. Littlewood, Chief Electrician — Strip Mill, Pittsburgh Works, Jones & Laughlin Steel Corp., Pittsburgh, Pa.

University Club, University Place, Pittsburgh, Pa.

AN IMPROVED D-C

. . . . this new d-c crane hoist circuit offers some new features not previously available . . . .

▲ CRANE users, builders, and electric control manufacturers all consider the load handling characteristics of a d-c dynamic braking control system to be quite desirable for almost all types of cranes. In fact, whenever a new a-c hoist control system is announced, the speed-torque characteristics of that system are always compared to the performance of a d-c dynamic braking circuit. As a result, very little has been done in recent years to analyze and improve the basic d-c circuit now in use.

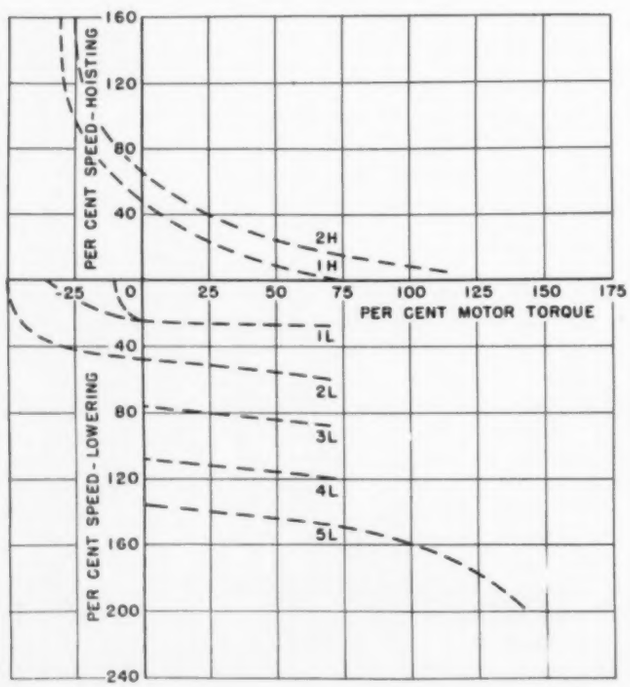
Since the beginning of World War II, an extremely large number of d-c operated cranes have been installed for the expansion of manufacturing facilities. The experience gained through the large quantity, plus the fact that many existing cranes were seriously overloaded in order to meet production requirements, led to the conclusion that several improvements could be made in operating characteristics.

REQUIREMENTS OF A GOOD CRANE HOIST SYSTEM

As a starting point in the design of a new circuit, a group of engineers responsible for the design and application of electric equipment to be used with the materials handling machinery agreed that it would be desirable to have a new crane hoist circuit which would provide the characteristics illustrated by Figure 1 and described below:

1. The first lowering point of the master switch should provide a speed-torque curve that is as flat as possible; so that there will not be any drastic difference in landing speeds for a light load or a heavy load. Assuming a gear efficiency of approximately 83.5 per cent, which would result in an overhauling motor torque equal to 70 per cent of the motor rating, the first point lowering speed of rated load should be less than 30 per cent.
2. The "kick-off" torque on the first lowering point should be on the order of 10-35 per cent in order to permit easy jogging. If the torque is less than 10 per cent, the motor may not start an empty hook down, because that amount of torque would probably not be enough to overcome the friction in the mechanical system. The operator might even have to hesitate on the first point of the master switch in order to jog a light load, since the low torque would require some time to accelerate the inertia of the system. On the other hand, if the torque is more than 35 per cent, a heavy load would be accelerated too rapidly for satisfactory jogging, and cable might be "paid out" so rapidly as to result in slack cable difficulties with an empty hook.
3. The "kick-off" torque on the second lowering point should be on the order of 50 per cent in order to permit rapid acceleration of a light load.
4. There should be no tendency for the lowering speed-torque curves provided on successive master switch points to approach or cross each other within the range from no-load to maximum-load. In other words, when the master switch is moved from one point to the next, there should be a definite speed change in the proper direction.
5. The fastest lowering point of the controller must provide stable motor operation up to at least 140 per cent of rated motor torque. With the efficiency mentioned in (1) above and on an installation that requires rated motor torque to hoist rated load, 140 per cent motor torque would be obtained when lowering 200 per cent of rated load.
6. The first hoisting point should provide sufficient stalled-motor torque to hold rated load without any downward drift. The speed-torque curve should be flat enough to permit taking up slack cable without excessive shock when the load is engaged, and the empty-hook speed should be around 50 per cent or less.
7. The second hoisting point should provide sufficient torque to lift rated load at a slow speed.
8. If at all possible, the first and second hoisting points should provide dynamic braking for rapid deceleration of an empty hook.
9. The number of devices on the control panel must be kept at a minimum to facilitate inspection and reduce maintenance.
10. There should be no "overshoot" in speed if the

Figure 1 — Desirable features for a crane hoist.



CRANE HOIST CONTROL

By S. RIFKIN
Industrial Engineering Divisions
General Electric Co.
Schenectady, N. Y.

master switch is moved rapidly from the "Off" position to any operating position, regardless of load.

11. The transient current and voltage peaks during either deceleration or acceleration must not be harmful. The control must be designed so that regardless of how erratically the master switch is manipulated, there will be no damage to the motor, control, or hoist equipment.

TEST PROGRAM

Before attempting the complete design of a new crane hoist circuit, a program of testing was undertaken on a hoist tower that is part of a control development laboratory. The object of this testing program was to prove the accuracy of a new system of calculating speed-torque curves[1]; to analyze the transient currents, voltages, and torques obtained on some existing hoist control systems; and to analyze the performance obtained with various basic motor and resistance connections.

*Numbers refer to bibliography at end of article.

Figure 2 — Developmental crane tower. Over-all height 85 ft; max load travel: 71 ft; capacity: 23 tons. Light load shown approximately at mid-point of tower.

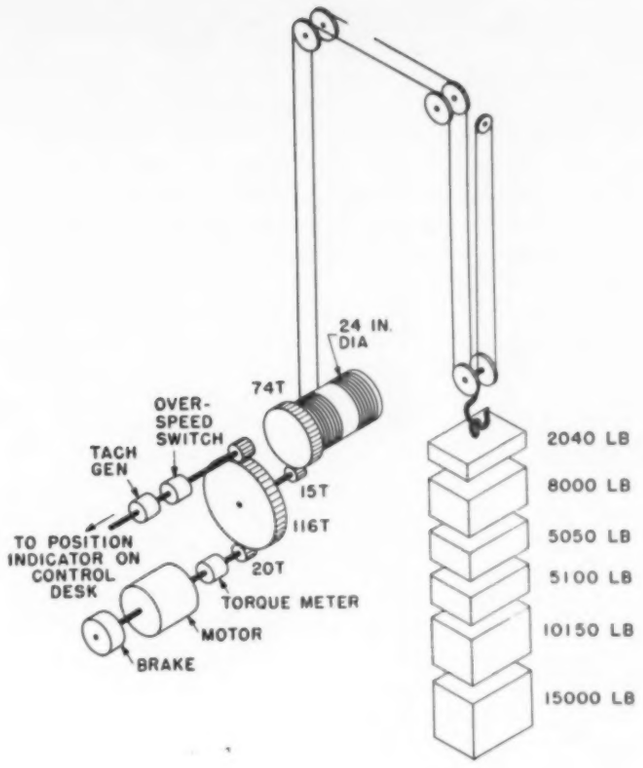


Figure 3 — Simplified mechanical diagram of test tower.

As a matter of interest, Figure 2 is included to show a view of the test tower. Figure 3 is a simplified diagram of the test tower mechanical system. Note that a torque-meter is provided between the motor armature and the pinion in order to measure actual torque in the motor shaft. This arrangement made it possible to determine the actual motor torque during transient as well as steady-state conditions by simply connecting the torque-meter to one element of an oscillograph during studies of transient operation.

Figure 4 shows the test motor mounted inside the development laboratory, where commutation can be readily observed. The motor shaft is connected to the torque-meter under the protective cover at the left of the illustration, and the torque-meter shaft extends through the wall to the gears and drum mounted under a sheet metal covering outside. Figure 5 is a view of the operator's stand in the same room as the driving motor. The instrument table is at the left; the master switch, speed indicator, and load position indicator are in the center, and the test panel is at the right, with resistors mounted above. This panel contains more contactors and relays than are actually necessary for any existing standard hoist circuit; so that the devices could be reconnected in any desired manner during the test program.

When MD-608, 45-hp, 470-rpm motor hoists the 45,340-lb load that is obtained with all of the weight shown in Figure 3 bolted together, the torque-meter reading is 174 per cent of rated motor torque. When this same load is lowered, the overhauling torque at the motor shaft is 148 per cent. Calculations made from these readings and from the mechanical diagram show a hoist tower efficiency of approximately 92 per cent.

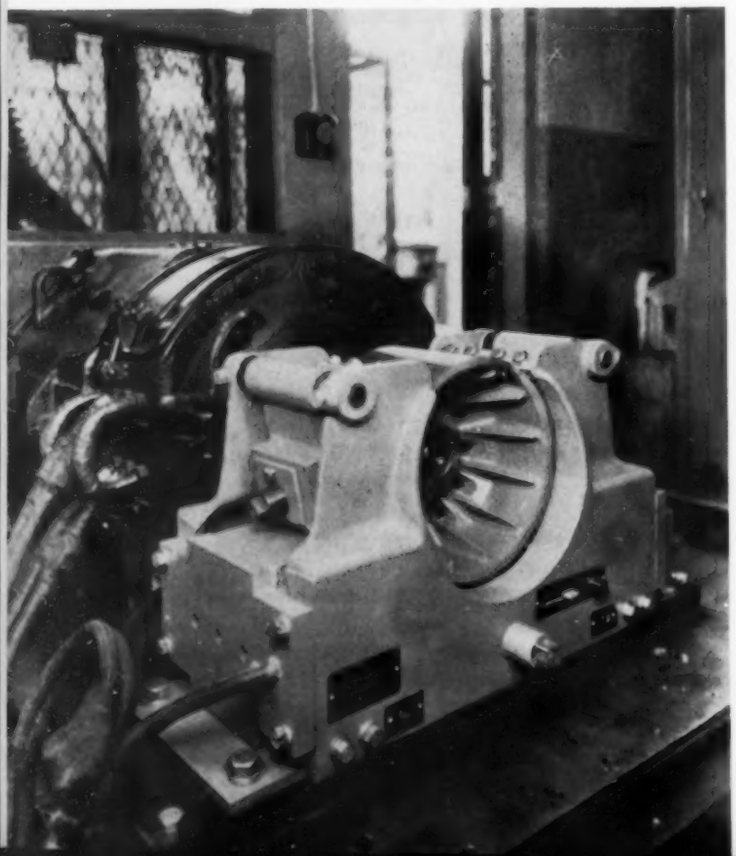
FUNDAMENTALS OF THE PROPOSED CIRCUIT

The motor stability mentioned under (5) above was considered to be the most important requirement in the design of a new circuit. Electrical engineers have known for many years that armature reaction has a very marked effect on the characteristics of d-c motors and generators running with weak field strength and heavy armature current. Those are exactly the conditions under which a series motor operates when lowering a load with a conventional dynamic-braking circuit. However, because the calculation of armature reaction was considered to be too involved, crane lowering characteristic curves have been published (and still are being published) without including the armature reaction effect. A lowering speed-torque curve that is shown as a straight line may actually break down at a surprising low value of torque, as shown for a crane duty motor by Curve (A) of Figure 6.

Heumann and Smith[1] have shown that the effect of armature reaction can easily be taken into consideration for a specific line of motors if both motoring and generating performance data are obtained for several different field currents with varying armature current. They also showed that motor stability can be easily understood by comparing the connections shown in (A) and (B) of Figure 6. After the series field circuit shown in Part (A) has been selected to provide the desired no-load lowering speed, the current in the series field is determined by the line voltage and is not affected by the current in the armature. As the load on the hook is increased, the regenerative armature current must also increase, since motor torque is proportional to armature current times flux. The increase in armature current results in increased armature reaction, which tends to oppose the flux established by the series field current. Eventually, the point is reached at which any increase in armature current is completely offset by the reduction in flux, so there is no increase in motor torque. In Part (A) Figure 6, this "breakdown" point occurs at approximately 100 per cent torque, 250 per cent speed. In comparison, note that when the regenerative armature current is increased in Part (B) of Figure 6, a portion of that increased current must flow through the series field; thereby opposing the armature reaction effect. However, the increased field current does not completely nullify the increased armature reaction; therefore, a "breakdown" point occurs at some value of torque greater than is obtained by the connection shown in Part (A). As the magnitude of the line resistance is increased, the torque at which "breakdown" occurs is also increased, although not in a direct ratio. The limit in the magnitude of the line resistance is determined by the necessity of drawing current from the line in order to lower an empty hook and also by the practical limit in the allowable voltage across the armature.

Figure 5 — Developmental crane-tower test table and control panel.

Figure 4 — Torque meter (under cover at left); MD-608 motor, 45 hp, 470 rpm, 30 min; and brake on test tower.



At approximately the same time that Heumann, Smith paper[1] was prepared, a cargo winch control was designed to provide improved motor stability through the use of line resistance. The cargo winch circuit was described in an AIEE Conference paper[2], and the performance of the large number of panels that have been supplied with that basic circuit has proven that the expected benefits are obtained in actual service.

Since the relatively large line resistance automatically limits the acceleration current peaks for lowering operation, there is no necessity of providing armature circuit resistance that has to be short-circuited or transferred on the fast master switch points. As a result, the desirable feature (4) of providing definite speed changes in the same direction as the movement of the master switch, regardless of load, can be easily provided by simply increasing the series field circuit resistance on successively faster master switch points.

Although it would be desirable to have the full-speed lowering characteristic of the controller provide approximately the same speed for both full-load and no-load, it is not possible to obtain that feature when a no-load speed on the order of 130 per cent or more is desired. With a no-load speed of 136 per cent and a hoist

efficiency that results in an overhauling torque of 70 per cent when lowering rated load, Figure 6 shows a published curve speed of 147 per cent for rated load, but an actual speed of 168 per cent on Curve (A). If a section of resistance were left in series with the armature, the slope of Curve (A) would be increased; thereby providing a faster full-load speed without any increase in the value of motor torque at which breakdown occurs. The rated load speed on Curve (B) would be 187 per cent, because line resistance increases the slope of the characteristic curve. However, the higher speed regulation is more than justified by the improvement in motor stability. Incidentally, Curves (A) and (B) apply only to one particular motor design, since the stability characteristics of all d-c motors are not alike.

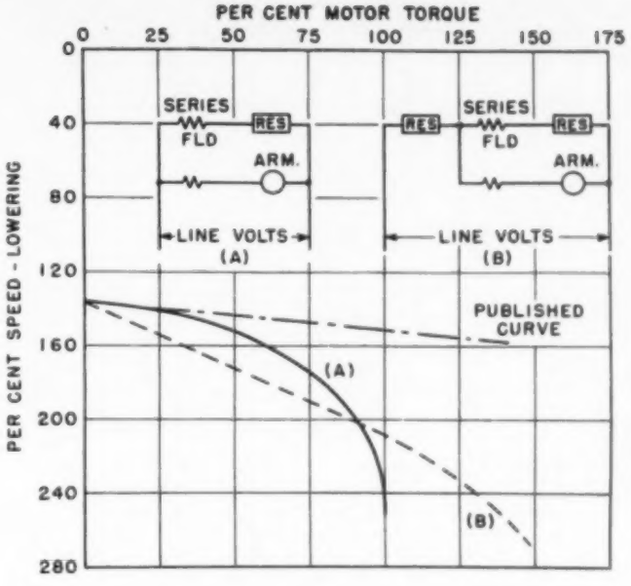


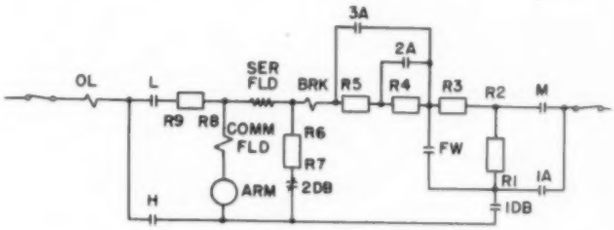
Figure 6 — Effect of line resistance on motor stability.

CIRCUIT DETAILS

The basic power circuit elementary diagram and the contactor sequence chart are shown in Figure 7.

In order to provide the desirable feature (6) of a slow empty hood speed on the first hoisting point and dynamic braking for rapid deceleration of an empty hook (8), an armature shunt connection is provided instead of the more commonly used motor shunt. Since the magnitude of resistor section R8-R9 provides the desired empty hook speed, the armature shunt connection is obtained merely by closing the L contactor. Then, sufficient torque to lift rated load at a slow speed on the second hoisting point (7) is obtained by leaving the armature shunt connection and by closing the 1A contactor to short-circuit the paralleled resistors R1-R2 and R2-R3. This slow hoisting speed can be extremely useful for accurate positioning work, such as lining-up a heavy shaft in a horizontal lathe. The remaining hoisting points are quite conventional and are obtained simply by removing the armature shunt and by a step-by-step reduction of the resistance connected in series with the motor armature and field.

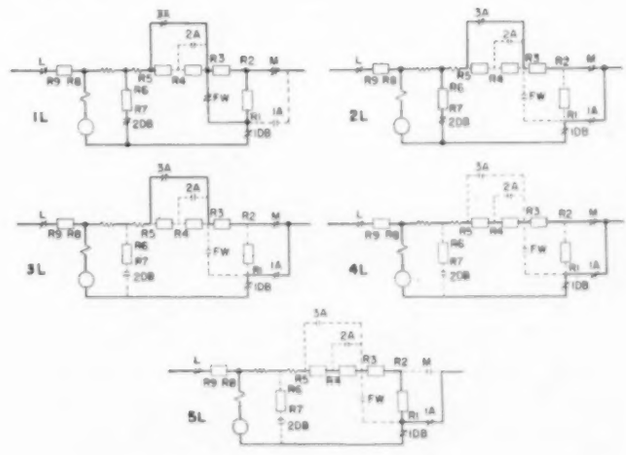
Figure 7 — Power elementary diagram.



	HOIST					OFF	LOWER					DECEL
DEVICE	5	4	3	2	1		1	2	3	4	5	
M	X	X	X	X	X		X	X	X	X		
L				X	X		X	X	X	X	X	
H	X	X	X	X	X							
1DB							X	X	X	X	X	X
2DB	X	X	X	X	X				X	X	X	X
1A	X	X	X	X					X	X	X	
2A	X	X										
3A	X						X	X	X			
FW	X	X	X	X	X	X	X					X

X - INDICATES DEVICE ENERGIZED

Figure 8 — Path of current on each lowering master switch point.



The step-by-step power circuit connections for lowering operation are shown in Figure 8, with the heavy lines indicating the paths through which currents flow on each point. As can be seen, the paralleled resistor sections R1-R2 and R2-R3 are connected in the line on the first lowering point and are added to R8-R9 to provide the desired low kick-off torque (2). The slow speed (1) is obtained by connecting the series field and brake.

On the second lowering point, the paralleled resistors are taken out of the line; thereby providing the desired stronger kick-off torque (desirable feature 3) and R2-R3 is connected in the series field portion of the circuit to increase the speed. On each of the remaining three lowering points, the speed is progressively increased by increasing the series field circuit resistance; thereby providing a definite change in speed regardless of load (4) and also preventing any "overshoot" in speed for rapid master switch movement (10).

The desired speed-load characteristics are obtained by the use of only eight normally open and one normally closed contactors. As in the past, the normally closed contactor is used to establish the emergency dynamic-braking connections.

Accepted practice is to include accelerating relays on magnetic control panels in order to establish maxi-

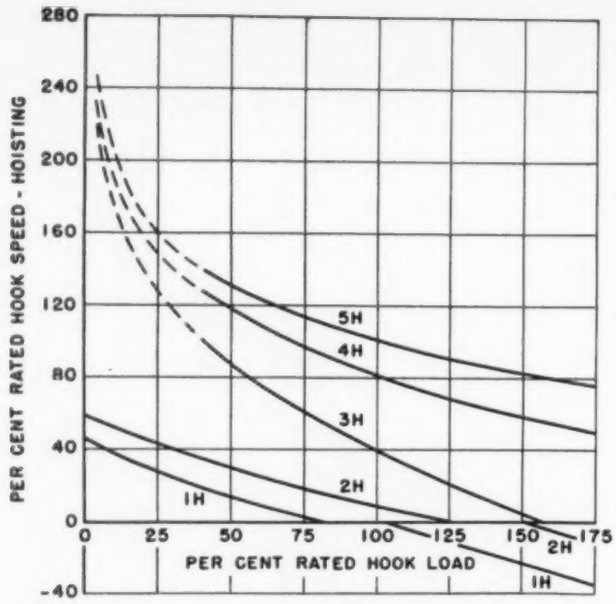
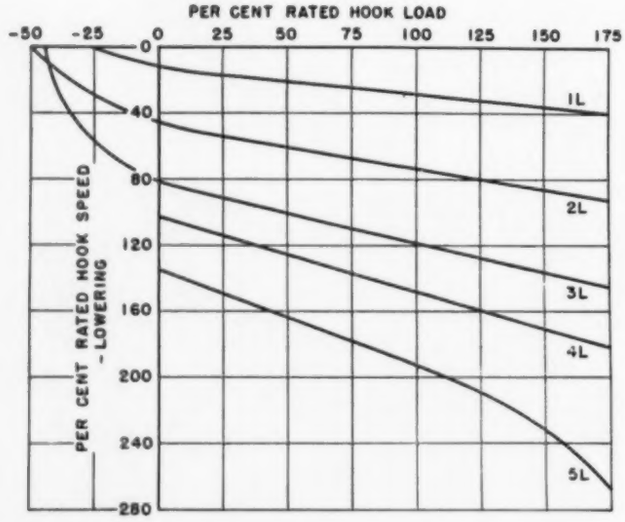


Figure 9 — Test curves — hoisting.

mum rate of acceleration for the protection of the motor and the mechanical equipment. Also, it is just as important to provide a maximum rate of deceleration when lowering an overhauling load. Therefore, in addition to the undervoltage and overload relays, the control circuit includes two accelerating relays, one decelerating relay, one plugging relay, and eleven auxiliary control contacts on the contactors for electric interlocking and sequencing purposes. Although there are two more relays and several more auxiliary control contacts than would be absolutely essential if the hoist were always under the control of a careful operator, the extra equipment is of considerable value by making it possible for the control panel to meet requirement (11) of protecting the electric and mechanical hoist equipment regardless of how erratically the master switch is manipulated.

Figure 10 — Test curves — lowering.



CONCLUSION

Figure 9 shows the characteristic hoisting curves obtained by means of the test equipment described previously. These curves are plotted as per cent rated hook speed vs per cent rated hook load, with 100 per cent hook speed defined as the speed obtained with the motor rotating at its 30-min rating, and 100 per cent rated hook load being the weight that can be lifted by the 30 min rated output torque of the MD-608 motor. Since the 10 per cent load and the empty hook never reached a steady-state speed on the third, fourth, or fifth hoisting points, broken lines are used in Figure 9 for that part of the test. Although a tachometer generator and a torque-meter were used to obtain the data, the curves are shown as per cent rated hook speed vs per cent rated hook load because that information is of more interest to crane users and builders.

The lowering curves are shown in Figure 10. In analyzing these curves, consideration must be given to the fact that the test tower efficiency was approximately 92 per cent. With the commonly encountered maximum efficiency of 85 per cent, the additional losses in the gearing would result in a lower overhauling torque at the motor for a given load, and the speeds shown in Figure 10 for 175 per cent load would actually be obtained with slightly more than 200 per cent load. Considering the variations in resistance due to resistor heating and the allowable tolerances in motor construction, these test readings check the calculated characteristics quite closely.

One of the well-known difficulties encountered in the use of a power type limit switch with a d-c dynamic braking circuit is the high speed obtained when lowering a load "out of the limits." The reason for the high speed is that the motor shunt connection obtained when lowering with the limit switch tripped does not provide a restraining torque, but actually aids the load in accelerating the inertia of the mechanical system and allows the load to drop more rapidly. When the limit switch resets, the normal lowering connections are established and there is a sudden jar on the mechanism, especially if the master switch is in a slow-speed lowering position. Reports have been received of accidents occuring when the power limit switch failed to reset, with the result that the maximum safe speed of the motor was exceeded before the operator could regain control of the load. In conjunction with the development of the new hoist circuit, a study of power limit switch operation showed that it would be possible to establish dynamic-braking connections for lowering "out of the limits." This connection would provide sufficient motor torque to drive an empty hook down and would limit the lowering speed to approximately the same value as obtained on the first master switch point regardless of the weight of the load or the actual position of the master switch handle. This connection requires only one normally open and one normally closed contact in the power limit switch, and eliminated the resistor normally used with the switch. However, in the hoisting direction, no dynamic braking is provided to assist the magnetic brake in stopping the motor. With an empty hook entering the limit switch zone at a motor speed of 1200 (225 per cent) on the test tower, it was

found that the new connections would stop the motor in approximately 24 revolutions, compared to 15 revolutions with the standard connections. On any installation where the limit switch zone can be increased by 60 per cent without seriously affecting normal operation, the safety feature of the new connections will undoubtedly be of considerable value.

As previously mentioned, all types of d-c motors do not have the same stability characteristics. For that reason, the same tests were made using a CO-1830, 50-hp, 525-rpm, 30-minute rated crane duty motor on the test tower. Since that motor has approximately the same rated torque as the MD-608, a comparison between these two motors could be readily made. Although the characteristic curve for the fastest lowering point tends to break away more rapidly at maximum load for the crane duty motor than it does for the mill duty motor, the control circuit was found to be entirely satisfactory.

A comparison of the speed-load curves in Figures 9 and 10 with the previously enumerated requirements of a good crane hoist system will show that each of the steady-state desirable features had been provided. Of course, the steady-state data was only a part of the information necessary to determine whether or not the proposed circuit would be suitable for crane use. In addition, oscillograms were taken to analyze the peak transient current, armature voltages, and shaft torque for rapid master switch movement under all possible conditions. These oscillograms were taken for rapid acceleration and deceleration in both the hoisting and lowering directions with a variety of loads ranging from an empty hook to 175 per cent of rated load. Analysis of the oscillograms resulted in control circuit connections for an automatic sequence of contactors that provides the most rapid possible deceleration with the least possible motor commutator distress and a minimum of brake lining wear. Figure 11 is an oscillogram taken for rapid master switch movement from the fastest lowering point to the "off" position with 117 per cent rated hook load, using a hoist circuit that has been widely accepted in steel mills for several years. The peak armature current of 520 amp occurs at approximately the same time as the 410 volt peak armature voltage. Setting the brake is delayed only by the time required for movement of the master switch and for decay of flux within the brake; therefore, the dynamic braking torque of the motor is still high when the brake sets, and the result is a torque peak in the motor shaft of 2730 lb ft. Figure 12 is an oscillogram for the same operating conditions using the new circuit. The first armature current peak is only 300 amp, the second is 450 amp at 378 volt, and the third is 510 amp at 280 volt. Heavy armature currents at high armature voltage and weak field strength results in arcing at the brushes and the possibility of commutator "flash-over"; therefore, the new circuit has a decided advantage. Also note that the setting of the brake is delayed by the decelerating relay, so that the maximum torque peak in the motor shaft is only 1760 lb ft. In addition, since the stored energy in a rotating system is proportional to the square of the speed, there is only 57 per cent as much energy to be dissipated in the brake with the new circuit as there is with the presently accepted circuit.

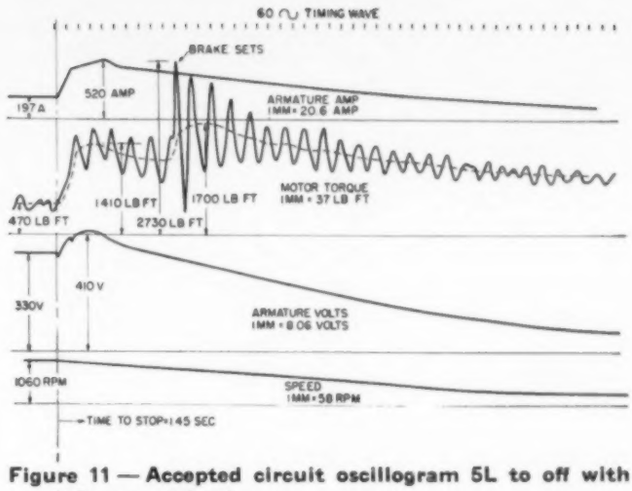
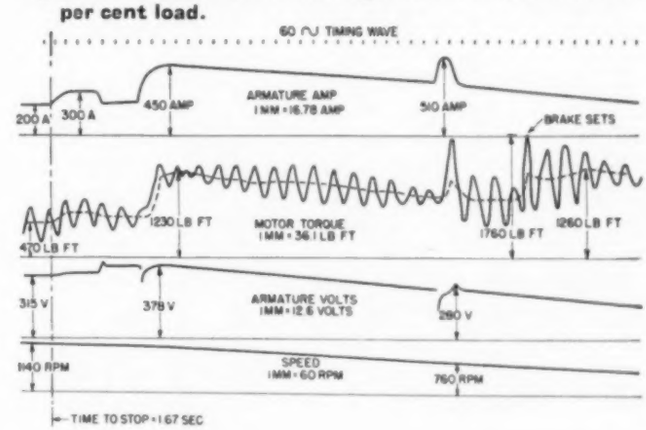


Figure 11 — Accepted circuit oscillogram 5L to off with 117 per cent load.

The two circuits used for Figures 11 and 12 were adjusted to provide approximately the same no-load speed (approximately 720 rpm) on the fastest lowering point. The connections provided by the accepted circuit on the fastest lowering point leaves a small amount of resistance in the armature circuit but no resistance in the line circuit. The armature circuit resistance results in almost as much slope to the characteristic curve as the line circuit resistance does in the new circuit, as evidenced by the speed of 1060 at the beginning of Figure 11 compared to 1140 on Figure 12. However, the armature circuit resistance does nothing to improve the motor stability. When an attempt was made to lower the 175 per cent load with the accepted circuit at full speed, there was a considerable amount of arcing at the brushes and the overspeed switch on the test equipment tripped at approximately 310 per cent speed to stop the motor before any damage resulted. Incidentally, both Figures 11 and 12 apply to the CO-1830 crane duty motor.

During the testing of the new circuit, it was found that if the master switch were thrown rapidly from full speed hoisting to full speed lowering with an empty book, the brake would fail to release and the motor would be stalled with slightly more than rated current flowing through the armature. This mis-operation was the result of a large amount of resistance being placed in the series field-series brake circuit before the armature could be brought to rest; consequently, almost all of the current flowed through the armature and the brake failed to release. When this same operation was

Figure 12 — New circuit oscillogram 5L to off with 117 per cent load.



performed with a moderate load on the hook, the force of gravity on the load would result in decelerating the armature before the series field circuit resistance was introduced; therefore, the brake would release and normal lowering operation would be obtained. In order to prevent the empty hook operation described above, the plugging relay was added on the panel to delay the introduction of series field circuit resistance for a definite period after the master switch has been moved from hoist to lower. This is just one example of the thoroughness with which the circuit has been designed and tested to make it "foolproof" regardless of how erratically the master switch is moved.

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2. *"A New D-C Control for Cargo Handling,"* by S. Rifkin and W. R. Morton. An AIEE Conference Paper, Pacific Coast Convention, August 28, 1946.

DISCUSSION

PRESENTED BY

H. S. SPITZ, Assistant Chief Engineer, Carnegie-Illinois Steel Corp., Chicago, Ill.

H. H. ANGEL, Electrical Engineer, Construction and Engineering Dept., Bethlehem Steel Co., Bethlehem, Pa.

C. L. EICHENBERG, Electrical Engineer, Electrical Dept., Bethlehem Steel Co., Bethlehem, Pa.

W. D. FALKENSTEIN, District Sales Manager, Electric Controller & Manufacturing Co., Pittsburgh, Pa.

H. K. HARDCASTLE, District Manager, Electric Controller & Manufacturing Co., Philadelphia, Pa.

S. RIFKIN, Industrial Engineering Division, General Electric Co., Schenectady, N. Y.

H. S. Spitz: Two of the crane hoist controls as described by Mr. Rifkin have been operating in our plant since the first week of January, of this year. These controls are installed on the hoist motion of the scrap yard cranes, handling scrap, pig iron and so forth, by means of 65-in. magnets on a continuous 24-hour, 7-day week basis. The motor on each hoist is an MD-412, 65-hp, 550-v, d-c, 470-rpm, one-half hour rated motor. The resistors are edgewise wound Class 172. These controls replaced equipment of the same manufacture installed about 1941.

A 550-volt d-c system such as we have at Phoenixville is very difficult and expensive to maintain at its best, and in a steel mill on "slam-bang" scrap handling service the ultimate is reached. Grounds are particularly troublesome due to working with the same clearances as on 250-volts and commutation is also poorer due to higher bar to bar voltages. Both of these conditions are aggravated by any transient peaks or punishment from faulty control.

For these reasons, we were immediately receptive to the idea of installing the new control as current and voltage peaks on deceleration had been eliminated together with overshoots in speed during deceleration. Furthermore, the increased stability when handling heavy overloads was of interest as frequently fu'l load is exceeded when unloading unprepared scrap such as heavy machine tools, castings, etc. The advantages of greater inching and positioning ability were of little importance to us on this particular application.

To date, after about 8 weeks' operation, the results have been very satisfactory and we can see no reason why they will not continue to be so. With the exception of a minor burning of the spring closed dynamic braking contactor 2DB, due to an intermittent low voltage condition on our feeder, there has been absolutely no maintenance or adjustments including contact tip replacement during these 8 weeks. This incidentally has since been compensated for by installing a lower voltage coil on this contactor to insure faster action.

These results are a decided improvement over the previous control as contact tips were replaced on the 2DB contactor on an average of every 2 weeks, and on the field weakening contactors 1FW, 2FW, and 3FW, on an average of every 3 weeks. In addition, there were numerous arching shield replacements, etc. One of the reasons for the improvement in the operation of the 2DB contactor is that it is no longer utilized as a motor shunt on the first two points hoisting.

The motor maintenance to date has been negligible. Commutation, when observed, has been very satisfactory, and there is no evidence of any arcing or flashover having occurred. Heavy arcing and flashover had been a frequent occurrence previously resulting in many armature, field coil, and brush holder replacements.

We have made an analysis in our plant with competitive controls in use and will report on this in a general way, only.

First, in Table I, the number of contactors and relays are compared with no reference to other devices as they are all essentially the same to the best of our knowledge.

You will notice that the new circuit has decreased the number of contactors by 2. Manufacturer "A" has 2 less relays than the new circuit but consequently does not offer deceleration in the lowering position. Manufacturer "B" has two additional contactors over the new circuit due to their method of reversing the series field and, thereby, eliminating the possibility of an armature contactor failing with the brake released permitting the load to drop.

Each of these four circuits subject the motor to rapid acceleration when lowering out of the limit switch with resultant rapid retardation and shock when the limit switch resets and dynamic braking is applied. As Mr. Rifkin showed in his paper, this can be eliminated by another circuit connection which eliminates the dynamic braking circuit in hoisting when the limit is tripped. I believe this warrants further discussion, and I

would appreciate hearing from the members regarding this point.

Another point regarding limit switch operation is that with Mr. Rifkin's circuit a "see-sawing" action in and out of the limit switch results, when overtravel occurs on the first or second point hoisting. This cannot occur with the circuit of Manufacturer "C" and only on the first point with the circuit of Manufacturer "B." This is not too serious with Manufacturer "B" as he can lift light loads only on the first point, whereas the circuit described in the paper tonight can lift 75 per cent load on the first point and full load on the second point.

It is our opinion that on our application this is not a serious consideration but, however, could be easily corrected by eliminating the armature shunt connection as we do not require the inching feature. However, on other applications where the inching feature is required and limit switch operation might be frequent with the resultant "see-sawing action," it warrants more consideration.

This action could be corrected by the addition of another relay and I request further discussion from the members expressing their views on this point, also.

TABLE I

	Author's company		Mfg. "A"	Mfg. "B"
	Old circuit	New circuit		
Contactors.....	11	9	9	11
Relays.....	8	8	6	7

H. H. Angel: I happened to be in Schenectady one day this past summer and saw this test tower in operation; it was quite a nice piece of machinery and you could actually play with the hoist control and operate it any way in which an average crane operator can recklessly operate his controls. One good feature about it, of course, was that you could operate it and see what was going on insofar as speed was concerned, field current, armature current, and armature voltage—and I believe they had a limit switch rigged up which you could operate at any time, and you could see what armature currents existed while the limit switch was being tripped, and while it was being reset.

As all of you know, there are a number of control manufacturers in the market today, and by and large all of the controls are working very well, but it may be that one manufacturer has a particular feature which somebody likes and somebody else does not like. Sometimes you can argue over a period of time on one particular point.

One of the things which Mr. Rifkin has brought out has been the prevention of a runaway, when you are lowering very heavy loads. A lot of cranes do operate with excessive overloads, but I do not think the average crane operator has overloads as high as 200 per cent. I think there is more abuse in the swinging of the blocks and abuse on the trolley in general than there is in having these excessive overloads, except under very special conditions. However, when an overload is handled, there is no excuse for the operator lowering this load at a very high rate, because if he just uses common sense and operates on the first, second or third points, the danger of a runaway condition may not exist. However, we do know those conditions may exist, and this circuit scheme should take care of that feature.

Our Lackawanna plant has one of these controls in operation since last December, and we just have a general report that it is working very satisfactorily. However, that is used on a crane which does handle heavy overloads at times and I believe it is operated very frequently on the first point or second point on lowering, in order to prevent what might be considered too great a speed. I am not referring, of course, to a dangerous speed, but just simply too great in general terms. They could have operated the control at a much higher lowering speed but they preferred not to take any chance.

Mention was made tonight about telegraphing of the limit switches. I believe in a good many controls where you have shunted armature connections, if you do leave the controller on a first or second point and operate the limit switch, you will get telegraphing.

However, a lot of people, as Mr. Spitz mentioned tonight, do not care for the shunted armature on the first point or second, especially on a job where you do not need very accurate spotting on either lowering or hoisting.

Another thing which was mentioned was the fact that this control eliminates two contactors. That is quite interesting because all of us would like to see smaller panels.

As a final remark, I again would like to call the attention of all the control manufacturers to the fact that one of the hopes of the steel and electrical men is that in the future we can get hoist controls, bridge controls and any other controls, which might be one-half of the present size. That has seemed to be an impossibility, but maybe some of these days we will have something like that.

C. L. Eichenberg: Mr. Rifkin is to be congratulated on his excellent paper describing the development of an improved d-c crane hoist control. The characteristic curves indicate that the performance meets every requirement of a good d-c hoist control. Mr. Rifkin's remarks regarding the elimination of telegraphing in and out of the limit switch on the first point hoisting are very significant. We have found that with certain limit switch operating weight designs, we have had to eliminate the motor shunt connection because of the possibility of holding the series brake circuit open while traveling into the limit switch at high speed. The connections just described will allow us to retain the desirable characteristic of a motor shunt on first point hoisting and prevent unsafe operation in the limit switch.

W. D. Falkenstein: Because I have been so thoroughly schooled over a period of years in the successful operation of the Wright dynamic lowering circuit, any remarks on hoist controllers are naturally biased. The paper tonight points out the necessity of stable motor speeds in lowering in order to obtain safety in handling full loads. D. C. Wright in the design of his circuit was conscious of possibilities of unstable speed of the motor in lowering loads and took this into consideration in the design and resistor layout. Our engineering department has always insisted that complete crane data be ob-

tained for each application. Consequently motor torques required in lowering can be determined. In this engineering of each application our chances of success are greater and as a result the circuit has developed an enviable reputation, especially in its ability to lower excessive loads with safety.

The paper makes a point of delaying the setting of the electric brake until the motor speed has been reduced by graduated dynamic braking. Most large crane users consider this as an unsafe set-up. An operator should have full control over his hoist so that in an emergency, he can apply the electric brakes and off-point dynamic braking to obtain the quickest stop possible. This ability to obtain a quick stop is essential on any crane that operates over production units or where men are working on the floor.

On such applications as ore bridges, bucket cranes and others, graduated dynamic braking has been incorporated in the Wright circuit. These applications do not involve the same safety requirements as mill and production cranes.

"Limit Stop Operation with Hoist Controllers" has been the subject of a number of papers. There has been considerable discussion in these papers of the advisability of shunts in the hoisting direction to obtain light torque creeping speed. These shunts prevent setting of the electric brake on tripping of the limit switch if the master is left on a hoist point that gives the motor shunt. The hoisting and lowering of the hook block under these conditions in the tripping zone of the limit switch, as mentioned, are more of an annoyance than a hazard. The real hazard develops if an operator is hoisting a light hook on the last point and returns his master to a hoist position that gives the motor shunt. Under this condition of high speed the local dynamic braking circuit may not stop the hoist in time to prevent the blocks from coming together. The stored energy in the rotating parts may be sufficient to break the cable. There have been enough unexplainable accidents due to dropping of hook blocks, and a number of safety engineers have tagged this holding of the brake open as the possible source of trouble.

Due to this possible hazard, a number of large crane users have written into their specifications the requirement that the electric brakes set on all points hoisting of the master switch on tripping of the limit stop.

Due to this pressure of crane users the Wright circuit was changed some time ago to eliminate this hazard. In practice it has developed that the slow creeping speed on the first point is more of a theoretical advantage than actual. On some special crane application the slow creeping speed is still supplied. Mr. Rifkin is to be congratulated on an excellent paper and his company for making public this valuable information and test data.

H. K. Hardcastle: I was very much interested in Mr. Rifkin's paper because we have been building dynamic lowering hoist controllers for a great many years and I do not recall a single case where a specified load got out of control when lowering.

You will recall that the run away point lowering shown on the curve, Figure 6, was figured at 175 per cent rated load, with efficiency of the crane 92 per cent. This corresponds to about 200 per cent load on an 85 per cent efficient crane, which would seem about normal. I doubt that even a steel operator would put 200 per cent load on a crane and lower on the last point of the controller. However, just in case he should, it is I believe, common practice for steel mill crane builders to overmotor their cranes.

However, we know that this condition exists with any dynamic lowering controller and for that reason we always get a crane data sheet filled out, from which we can figure the safe lowering speed of the maximum load this particular crane will handle, and proportion the values of the lowering resistance accordingly.

It has always seemed to me that this was primarily a question of stability of the motor, and I was wondering about the resistance values used, or the per cent of field weakening allowed on the last point lowering with this new circuit. There is a possibility of some difference brought about by difference in the characteristics in the new line of mill motors.

S. Rifkin: I am in full agreement with Mr. Angel's and Mr. Hardcastle's comment that very few cranes are subjected to large overloads. However, Mr. Spitz has pointed out that his scrap yard cranes are frequently overloaded when handling heavy machine tools or castings, and Mr. Angel mentioned that heavy overloads are handled at times on the Lackawanna crane. We welcomed the opportunity of obtaining field experience for the new control on both of these installations because of the excessive motor maintenance that had been involved. For example, the records of the Lackawanna crane showed an average of two to four motor breakdowns a year over the past eight years, and many of those breakdowns were considered to be the result of excessive loads. The sample control panel has been in service on this crane since December 7, 1948, without a single motor breakdown. (These comments are being written on October 11, 1949.) Although we realize that ten months service is not conclusive evidence that a motor breakdown can never occur, still the record is a remarkable improvement over the past experience.

The practice of obtaining load and mechanical information on the crane data sheet mentioned by Mr. Hardcastle is quite desirable. Several years ago, we attempted to obtain that data on each order, but found that the time involved resulted in delaying promised shipments. We are quite pleased to learn that Mr. Hardcastle's company has been successful in following that procedure, as we are once again asking all our customers for the necessary data. However, we must all realize that the crane data sheet is not a complete solution to the problem of excessive loads. The engineer who fills in the data sheet is not the same man that places the slings on the hook. At one time, any indication that a crane had been overloaded without the approval of someone in authority was sufficient cause for immediate dismissal of both crane operator and crane follower, but in recent years, many mills have been unable to enforce such strict adherence to loading rules. Consequently, there can be no disagreement with the desirability of increasing the magnitude of the overload that can be lowered safely, as long as none of the other desirable operating characteristics need to be sacrificed and there is no additional expense involved.

Mr. Falkenstein has mentioned that graduated dynamic-braking is considered unsafe. That is an argu-

ment that has been carried on in generalities for many years. Of course, the answer depends upon the design of the graduated dynamic-braking circuit; so I would like to refer to the facts shown in Figure 11 and Figure 12 of the paper. As you will note, the new circuit brought 117 per cent load to rest from full lowering speed in only 0.22 seconds longer than the accepted circuit. That is well within the difference in reaction time for different operators, but, for the sake of argument, let us assume that the reaction times are the same. On the test tower, load speed in fpm is equal to 0.11 times motor rpm, as can be verified by the data given in Figure 3. While the motor was decelerating from 1140 rpm to rest, the average load speed was 12.5 in. per sec. Therefore, 117 per cent load moving at 125 fpm was brought to rest within 0.22 seconds or 2.75 in. of the distance required if graduated dynamic-braking had not been provided. That still is not the complete picture, because in an emergency, the operator's natural reaction would more likely be to throw the master switch handle into the hoisting direction in an attempt to plug the motor. The new circuit has been designed so that with 117 per cent load on the hook, the master switch can be thrown from full speed lowering to full speed hoisting without tripping the overload relay. Another oscillogram shows that the load can be brought to rest in 0.97 seconds by operating in that manner, which is two-thirds of the time that would be required if the overload relay were allowed to trip and to result in normal off-position stopping. Therefore, from the viewpoint of safety, motor commutation, and brake wear, the graduated dynamic-braking circuit has definite advantages.

Mr. Spitz, Mr. Angel, Mr. Eichenberg, and Mr. Falkenstein have all mentioned complications arising from power limit switch operation. Actually, two entirely independent problems are involved—one is the fast lowering speed obtained when coming "out of the limits," and the other is cycling "in and out of the limits," if the master switch is left on the first or second hoisting point. As I stated previously, we have developed a method of restricting the speed coming "out of the limits" to approximately the same value that would normally be obtained on the first lowering point. Even if the limit switch failed to reset, the load could be lowered through the full distance at the slow speed. That desirable feature was obtained only by providing sufficient head room in the limit switch zone for the magnetic brake to stop the empty hook without any dynamic-braking assistance; therefore, that feature will be provided only when it is requested.

As for the cycling operation on the first two hoisting points, Mr. Falkenstein has correctly pointed out the serious hazard that exists if the limit switch dynamic-braking circuit is depended upon to stop the empty hook with the magnetic brake released. However, a close analysis of the new circuit will show that with the limit switch tripped on the first two hoisting points, a plugging connection is established instead of a dynamic-braking circuit. That is one of the advantages obtained by using the L contactor for the armature shunt circuit. Tests have proven that the plugging circuit will stop an empty hook running at maximum speed just as rapidly as the normal combination of magnetic brake and dynamic braking.

Of course, that still does not answer the objections to cycling in and out of the limit switch zone. At the time this paper was written, we did not have a completely satisfactory solution to that problem, but we firmly believed in the desirability of a stable, slow, empty-hook hoisting speed, even if the slow speed were used only to take up slack cable without excessive jogging. We also believed in the desirability of enabling an operator to slow down an empty hook from maximum hoisting speed without setting the brake. Therefore, in order to eliminate the cycling operation without sacrificing the armature shunt features, we have developed a method that requires only an additional shunt wound relay to remove the armature shunt connection when the power limit switch trips. That extra relay is being provided on all standard panels.

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STUD WELDING SPEEDS STEEL PRODUCTION

By ROBERT C. SINGLETON
Nelson Stud Welding Div.
Morton Gregory Corp.

. . . . stud welding has proved a very useful tool in steel plant maintenance work for open hearth doors, wet skid tubes, open hearth burners and crane rails . . . .

▲ WITH the entire steel industry exerting every effort to expand capacity in order to meet the accelerated demand of a war emergency imposed on top of extraordinary consumer requirements, any new technique method which results in increased mill capacity or longer operating life for essential equipment assumes greater importance than ever before. Despite the giant strides made by steel producers since the war in stepping up their productive facilities, mill products are still in very heavy demand.

In many cases, the theoretical capacity of an open hearth is limited by the practical necessity of relining the furnace or taking other similar preventive measures. While it may seem that improvements in these highly developed operations would not add any appreciable output, experience has shown that in at least one of these maintenance items, the savings possible through new techniques are definitely worthwhile.

Perhaps no subject is more controversial among steel operating men than that of open hearth doors. Not only do individual companies vary widely in their preferences, but divisions and even individuals in a single company have strongly held likes and dislikes. In any case, operating men fully realize the importance of developing the best possible door — one which has a long life, is economical, and above all quick and easy to repair and replace.

On all modern open hearths, the doors in front of the furnace consist of a steel frame, an insulated surface which is exposed to the interior of the furnace, and a water jacket behind the brick or chrome ore insulating material. In recent years many special doors have been developed in an attempt to obtain the longest possible door life, but all contain these three basic elements.

Proper selection of an open hearth door depends upon many factors, but in the last analysis the basic problems involved are: which door costs the least to use over an extended period, and which door results in the least amount of lost steel production.

Recent developments in open hearth door design which combine the use of plastic chrome ores and end welded studs have proved that this combination is an excellent one for certain types of open hearth furnaces.

In one open hearth mill in the Chicago area, a close study of both brick doors and studded and rammed doors has shown that the rammed doors result in cost savings of better than $35,000 over brick doors during a period of one year, and that the eleven furnaces involved are able to increase their production by more than 2500 tons during the same period.

Although all open hearth doors were originally designed for use with bricks of various sizes and shapes, many mills have swung to a door designed for use with a chrome ore ram mix. Regardless of the type of door being used, end welded studs have proved an extremely satisfactory means of supporting the ram mix.

This mix is usually a neutral refractory material made of iron and chrome ores with a water glass or sodium silicate binder. When properly rammed and cured, doors made with this material are capable of withstanding more than enough heats to counter the increased initial cost of this type of door when compared to brick doors. Many operators have found that on a strictly cost per door per heat basis, studded and rammed doors are less expensive, and have the added advantage of lowering labor costs and keeping production losses during door changes to a minimum.

The solid back or tank type door is the most commonly used with ram material. The main advantage of this door is the fact that the entire surface is water cooled. The studs which support the ram material are welded directly to the back plate of the door. A variation of this door is the combination panel door, which includes a series of peepholes for determining the condition of the door insulating material from the outside of the furnace.

The true panel type door, originally designed for use with refractory brick, is also adaptable to the studded

and rammed construction. Filler plates may be welded into position between the panels to make the door similar in construction to the combination panel door mentioned above.

Three factors are of particular importance in preparing a studded and rammed door. These are:

1. Stud size and spacing.
2. Proper ramming procedure.
3. Correct curing of the ram material.

The end welded studs used in an open hearth door serve two important purposes. One is to provide proper support for the chrome ore ram material. The other function is to provide a heat transmission path from the hot surface of the door to the cooling tank behind in order to keep the insulating material as cool as possible.

Selection of the proper stud size and location depends somewhat upon local conditions and individual preferences. However, a few basic principles apply. Generally speaking, ½-in. studs are placed on 2½ or 3-in. centers, while ⅝-in. studs are on 3-in. centers, with ¾-in. studs on 3 or 4-in. centers. In any event, the studs should be located on the door in such a manner as to assure straight lines. When studs are welded to a door for the first time, chalk lines or a simple wood template can be used. When studs are welded on 3 or 4-in. centers, it is advisable to weld additional studs in the center section of the door immediately above the wicket, since this is the area of greatest deterioration.

The proper transmission of heat from the face of the door to the cooling tank depends almost entirely on the bond between the stud and the back plate. Here, the automatic features of the stud welding process prove valuable, since each weld joint represents a complete union between the stud and the plate. Extensive tests have shown that a ½-in. end welded stud is equal in heat transfer qualities to a tackwelded ¾-in. stud.

Many steel producers are using ½-in. studs, since only a single welding generator is required. However, others prefer ⅝-in. studs due to the greater heat transfer resulting from the larger section.

Once the studs have been properly end welded in position, the next step is to ram the chrome ore into the space between the studs. Since the length of life of the open hearth door depends to a great extent upon the conditions of the insulating material, it is important to take a few simple precautions in ramming the material into position.

Three major factors should be considered in selecting the ramming method. These are:

1. The material should be rammed in such a way that maximum density is obtained. This will avoid air pockets, hot spots, improve heat transfer qualities, and prevent spalling.
2. The insulating material should be free of laminations parallel to the surface of the door to avoid spalling.
3. The door must be cured properly to drive out most of the moisture and thus avoid formation of steam pockets.

The most common ramming method now used is to

Figure 1 — First step in preparation of rammed and studded open hearth doors is to remove the old chrome ore mix from the door. Here, an air hammer is being used to chip away the ram mix and the nubs of the end welded studs.

Figure 2 — A scarfing or rivet cutting torch is applied to the back plate of the door to burn off the nubs of the end welded studs. Studs should be welded in the same location each time the door is repaired, and this burning process effectively removes all surface material that might interfere with a good weld joint between the stud and the back plate. Proper preparation of the door before welding is essential to long door life.

Figure 3 — Studs are end welded to the back plate of the open hearth door by the portable stud welding gun. The studs are welded in straight rows to facilitate ramming the chrome ore into the door. Consistent positioning of the studs is assured when new studs are welded in the location of the previous ones.

place large chunks of the ore in the door and then pack it into position by means of iron poles or bars. The chunks should be larger than the thickness of the door to avoid laminations which would be built up if small pieces were used. The main disadvantage of this method is that it is difficult to obtain a uniform high density across the entire surface of the door.

A variation of this method is to use a spade-shaped tool to cut up the chunks of ore. The ore is added in two layers, but the action of the spade results in laminations which are at right angles to the surface of the door, not parallel to it. This method is recommended if hand ramming is used.

An air gun with a round-nosed or blade-like tool can also be used. The same precautions about building up layers of the ore still apply.

After the ramming is completed, the surface of the door should be evened off with a trowel or spade. The ram ore should not extend past the ends of the studs by more than $\frac{1}{8}$-in., since this portion will spall off immediately.

The door surface should be left rough. If the surface is slick, it should be roughed up with a wire brush. This item is important, since floating or slicking the surface draws the binder in the mix to the surface, where it forms an impervious crust, and makes drying operations difficult. Of equal importance is the fact that the material below the surface is deprived of the necessary binder, thus increasing chances of early failure.

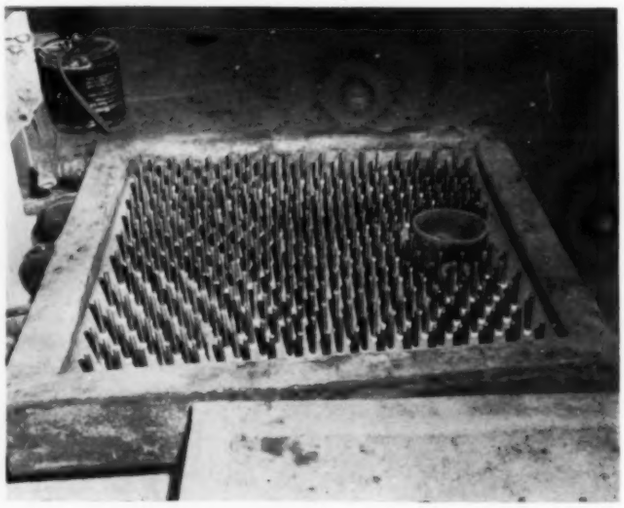
The doors must be cured before they can be installed, since the ram mixes contain an excessive amount of moisture to assist in working the material. The most common curing method is to circulate steam through the water cooling tank of the door. While being cured, doors should be in a horizontal position, and should remain that way until ready for use.

After a door has been removed from an open hearth furnace for relining, it is important that it be prepared properly. The first job is to remove the slag and remaining ram material with an air gun or chipping hammer. Then, all of the studs should be removed by a scarfing or rivet cutting torch, and the interior surface of the door swept out.

Complete removal of all of the old studs is particularly important to the proper operation of the door. One reason is that the new studs should be end welded to the back plate in the same position as the old ones. This prevents a build up of old ram material, makes packing easy, and lengthens the life of the door. Another reason that the new studs should be welded in the same position each time is that perfect welds are obtained, since the burning action of the torch removes all old metal and ram material from the welding area. This item is of considerable importance, since one of the major functions of the studs is to carry heat away from the surface of the door to the cooling tank, and a solid union between the stud and the back plate is essential. Unless the nubs of studs are removed each time a door is changed, the entire surface of the door will become covered with a layer, consisting of nubbins, chrome ore and slag, which forms a barrier that reduces the cooling effect of the water.

Determination of total costs of studded and rammed doors involves several factors in addition to the initial cost of the completed door. Experience has shown that in many instances the door cost per heat is lower with studded and rammed doors. In addition, there are other factors which must be considered before a complete cost analysis can be made, and here too this type of door has proved economical.

Figure 4 — This shot of an open hearth door after the studs have been end welded in position shows how they should be welded in straight lines across the door surface. Extra studs are often welded in the area immediately above the wicket, since this is the point of first deterioration. Spacing between the studs varies with the size being used. The studs serve to support the chrome ore mix and furnish an efficient heat transmission path from the door surface to the water cooling tank.



While the figures used below are hypothetical and intended to represent average figures found throughout the industry, they are based upon actual experiences in several prominent open hearth mills. Undoubtedly these items will vary with local conditions, but the following costs are intended only as examples which can be changed to meet conditions found within any one plant. In some plants, operating conditions preclude entirely the use of this type of door.

Three major items must be considered in determining the total cost of keeping open hearth doors in operating condition during an extended period.

Initial door cost is one of these elements. Generally speaking, a studded and rammed door will cost 5 to 7 times more than a brick door. However, the average number of heats obtained from a rammed door may be as many as ten times greater than the number which a brick door can stand.

Direct labor costs are another important item. While the job of changing the door itself may not require more than 2 or 3 minutes, the actual time consumed may be considerably longer if it is necessary to wait for cranes, workmen, etc. A conservative estimate of the direct labor costs involved in changing a door is $5.00, counting the time of the millwright, craneman, and other operators. In the same manner the heat time lost whenever a door is changed may amount to five minutes or more, depending on local operating conditions and assuming that the furnace is off the line while the door is being changed, in accordance with established safety practices. Assuming a cost of $60.00 for operating an open hearth (above the cost of raw materials) this lost time amounts to another $5.00 every time a door is changed.

A third factor to consider is the fact that steel production itself is decreased whenever a door is changed. Again, conditions vary from plant to plant, but this lost production is particularly evident in mills where all heat is turned off while a door is changed. Generally speaking, two minutes' time is required to build up heat within a furnace for every minute the heat is turned off. Even when only five minutes are required to change a door, one ton of steel is lost every time a door is changed when the furnaces are producing at an average rate of 12 tons an hour. Thus it can be seen that production losses can be kept to a minimum by changing the fewest possible number of doors.

TABLE I

OPEN HEARTH DOOR COSTS

Door	Type of door: Studded and rammed	Type of door: Brick
1. Average cost of door complete	$ 125.00	$ 16.00
2. Average number of heats per door	150	15
3. Heats per door change (Heats per door ÷ 5 doors per furnace)	30	3
4. Cost/door/heat (Line 1 ÷ Line 2)	$ 0.83	$ 1.07
5. Total number of heats per year (340 working days x 2¼ heats per day)	765	765
6. Single door cost per year (Line 4 x Line 5)	$ 635.00	$ 820.00
7. Total mill cost of door preparation (Line 6 x 11 furnaces x 5 doors/furnace	$34,925.00	$45,100.00
Door handling costs (approximate)		
8. Estimated labor costs per change	$ 5.00	$ 5.00
9. Cost of lost furnace time per change (Operating costs of $60/hour and five minutes per change)	$ 5.00	$ 5.00
10. Total of lines 8 and 9 = Cost per door change	$ 10.00	$ 10.00
11. No. of doors changed per year per furnace (Line 5 ÷ Line 3)	25.5	255
12. Total No. of doors changed = 11 furnaces x Line 11	286	2805
13. Cost of handling doors per mill (Line 10 x Line 12)	$ 2,860.00	$28,050.00
Tonnage (approximate)		
14. Minutes lost per door change	5	5
15. Tonnage lost per change (12 tons per hour, 5 minutes lost)	1	1
16. Total tonnage lost per furnace (Line 15 x Line 11)	26	255
17. Tonnage lost per mill (Line 16 x 11 furnaces)	286	2805
Summary		
Annual direct door cost (Line 7)	$34,925.00	$45,100.00
Annual door handling cost (Line 13)	$ 2,860.00	$28,050.00
TOTAL	$37,785.00	$73,150.00
Annual tonnage lost	286	2805

Figure 5 — Large chunks of the chrome ore ram mix are broken up and forced into the spaces between the studs. Here, the operator is using an air hammer with a shovel blade attachment to pack the mix with uniform density across the door. Careful preparation at this point will eliminate early spalling of the mix.

In order to demonstrate the cost savings possible and the steel production increases possible when studded and rammed doors are used in place of brick doors, the following comparison sheet has been developed as the result of a close cost study made at a Chicago mill which has eleven furnaces. Although these figures are for one particular plant and will vary throughout the country, they are representative of experience in the industry to date.

Heats per day	2¼
Hourly production per furnace	12 tons
Hourly production costs	$60.00
Number of furnaces	11
Number of doors per furnace	5
Brick door life	15 heats
Brick door cost	$16.00

Figure 6 — Studded and rammed doors are laid flat while they are being cured to remove excess moisture from the chrome ore mix. Some venting, as shown above, is necessary to speed the drying process and to eliminate potential steam pockets. The doors should remain flat until they are ready to be installed on an open hearth door.

Studded and rammed door life	150 heats
Studded and rammed door cost	$125.00
Direct labor to change door	$5.00
Lost furnace time per change	5 minutes

Table I shows the spectacular cost savings and important production increases that are possible when studded and rammed door is used in place of the brick door, under those conditions when brick door life is of the order noted.

Even under more unfavorable conditions, when the studded door will only last 100 heats, the total door changes required during a year (in this same plant) would be only 38, as compared to the 255 required for brick doors. In this case, the total mill cost of door preparation will be about $7000 greater for studded doors, but the door handling costs will be $26,000 less, resulting in a net saving of some $19,000. Under these conditions, the tonnage lost when brick doors are used remains at 2805, but only 418 tons of steel are lost when studded and rammed doors of low-heat life are used.

While it is true that rammed doors using other methods of supporting the mix have proved satisfactory, the advantages inherent in the stud welding process are sufficient to make this technique worthy of serious consideration. When compared to hand welded studs, end welded studs can be welded in about ⅓ the time, and offer far better heat conductivity, and therefore increased door life.

Other applications of stud welding have proven equally successful in prolonging the operating life of other vital steel plant accessory units. One typical application is the use of stud welding for securing chrome ore to the skid tubes and nose sections of slab reheating furnaces. Here, special collar studs are used to hold the insulating plastic chrome ore in position.

Replacement, maintenance, and proper location of craneway rails is a continuous problem in most mills. Several plants are now using ⅝-in. studs welded directly to the beams or girders which support the rails. Bent dogs are then used in conjunction with the studs to hold the rails in their location. The dogs are spaced at intervals of about one foot along the rails, and then fastened to the studs.

GEORGE MICAN WINS KELLY AWARD

▲ THE 1949 prize winning Kelly Award papers were selected by the Board of Directors at their meeting on September 25, 1950. First prize was given to George S. Mican for his paper, "Deformation in Rolling." Mr. Mican is division superintendent, rolling, Carnegie-Illinois Steel Corp., South Works, Chicago, Ill. This paper was published in the February 1949 issue of the Iron and Steel Engineer.

Second prize was awarded to A. J. Fisher, assistant chief engineer of construction, Bethlehem Steel Co., Bethlehem, Pa., for his paper "Fuel Oil in the Steel Industry," which was published in the April 1949 Iron and Steel Engineer.

K. N. Bundy and P. E. Jordan of the Wheeling Steel Corp. share third prize for their paper on "Water Pollution Control in the Steel Industry," which was published in the April 1949 Iron and Steel Engineer.

The Kelly Award carries prizes of $300, $200 and $100 for first, second and third places, respectively. The award was established September 28, 1943 to honor John F. Kelly, managing director of the AISE from 1917 to 1934, and to perpetuate the memory of his achievements in the advancement of the Association.

The award is made each year by the board of directors of the AISE upon the recommendations of the editorial and executive committees of the Association.

Rules of the Award:

1. The Award shall be given annually to the author of the paper adjudged of greatest value in the advancement of engineering or operating practice in the iron and steel industry.

2. The entries for each judging shall be the papers published in the Iron and Steel Engineer during each calendar year, although some may have been presented at meetings in the previous year. Voluntary contributions of papers not presented at meetings but published by the Association are also included in the judging.

3. To be eligible for the Award, the author must be directly employed in the iron and steel producing industry. The author need not be a member of the Association of Iron and Steel Engineers.

4. The Award shall be made at the annual fall meeting following the close of the calendar year.

5. The Award shall be made by the board of directors of the Association on the recommendation of the executive committee of the Association.

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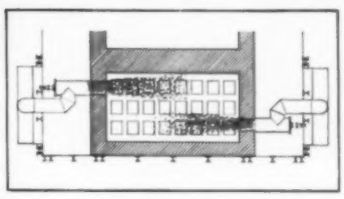
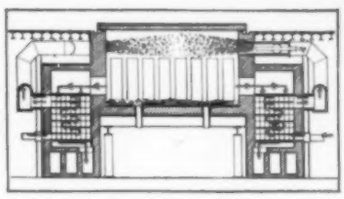


PLAN VIEW



CROSS SECTION

Thanks to superior design, Rust Soaking Pits have greater charging capacity per square foot of area. Sketches above indicate the diagonal two-way firing, by which heat is distributed uniformly throughout the pit; on cut backs both ends of pit remain in balance, thus ingots soak out evenly. absence of impingement increases life of refractory walls and covers.

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ONE RUST CONTRACT covers everything . . . from blueprint to test-run. Rust assumes responsibility for design, manufacture and erection of all essential material . . . including excavations, foundations, wiring and piping. Your purchasing and engineering departments are freed of subcontractor headaches when you order from Rust.

F-3

RUST FURNACE CO.

"PIONEERS IN FURNACE DESIGN"

PITTSBURGH, PENNSYLVANIA

Pictorial Roundup . . .

AISE CONVENTION AND IRON AND STEEL EXPOSITION

CLEVELAND, OHIO

SEPTEMBER 26 - 29, 1950

The 1950 AISE Convention and Iron and Steel Exposition was the most successful held during the 43-year history of the Association. The attendance of 10,867 persons included operating executives and engineers from steel plants all over the world. Technical meetings and exhibits were held in the Cleveland Public Auditorium. The exhibits of 154 companies were most interesting and idea-provoking. The exhibits occupied the Arena Hall (1) and the Exhibit Hall. Technical meetings were held in Club Rooms A and B and the Ball Room of the Auditorium. Preceding each day's sessions, an authors and chairmen breakfast was held. Participants in some of the sessions are shown in (2), (3), (4) and (5). The Old Timers held their annual get-together on (6) Wednesday, September 27 at the Hotel Statler.

During the Convention, the AISE Board of Directors announced the election of 1951 officers (7) of the Association: John F. Black, Youngstown Sheet and Tube Co., AISE president; John L. Young, National Tube Co., AISE 2nd vice president; E. L. Anderson, Bethlehem Steel Co., AISE treasurer; I. N. Tull, Republic Steel Corp., AISE 1st vice president; and John H. Vohr, Carnegie-Illinois Steel Corp., (not shown), AISE secretary.

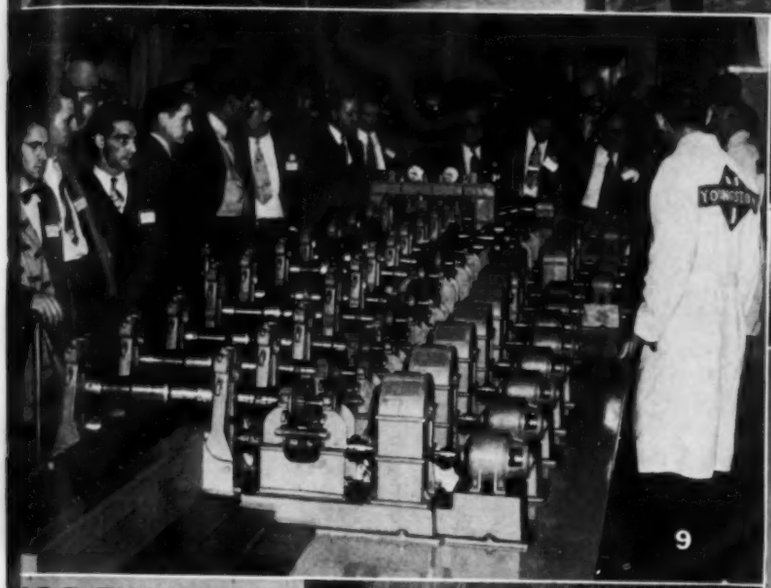
The inspection trip on Wednesday, September 27, to the Lorain works of the National Tube Co. was participated in by 1139 members and guests (8) who strained the available transportation facilities.

The Iron and Steel Exposition featured many models. One of the attention-getters was the model of an electric weld tube mill (9). The invention of a new self-centering roll was announced during the convention by E. T. Lorig, Carnegie-Illinois Steel Corp. Working models (10) of these rolls were on exhibit. Other interesting exhibits are shown in (11), (12), and (14). A contingent of southern engineers visit the exposition (13).

R. O. Keefer, Aluminum Co. of America and Clifford S. Strike, F. H. McGraw and Co. (15) and H. B. Jordan, American Steel and Wire Co. (right in 16) presented papers at the general session on Thursday, September 28. A. S. Glossbrenner, Youngstown Sheet and Tube Co., 1950 AISE president, (left in 16) presided as chairman.

The Exhibitors Dance was held Tuesday, September 26 and the annual Dinner and Dance was held Thursday evening, September 28. Numerous events were held for the ladies who accompanied their husbands.

8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16

DOWELL SERVICE

CHEMISTRY APPLIED TO MAINTENANCE CLEANING PROBLEMS

A Steel Plant asked: "Can you clean blast furnace stoves?"

Dowell Service cleaned two stoves in four working days!

The gas heating efficiency of two blast furnace stoves had fallen to 63.6% and 64.6%. In four working days, *without dismantling*, Dowell Service raised the efficiency of these stoves to 82.7% and 79.0%.

Before Dowell Service, the first stove producing a blast of 1350°F., averaged 110 minutes on the furnace. After Dowell Service this stove could be kept on the furnace an average of 143 minutes. The other stove, producing a blast of 1400°F., could be kept on the furnace 24 minutes longer after Dowell Service.

Other equipment in the gas cycle—dust catchers, gas washers, precipitators and gas lines—has also been cleaned *rapidly, economically* and effectively *without dismantling* by Dowell Service. Gas washers and blast furnace cooling systems have been cleaned in a few hours without interrupting operations.

In Dowell Service, special liquid solvents are pumped or sprayed into the equipment to be cleaned. These solvents are designed to dissolve and disintegrate deposits from all surfaces, even the most complex, *in a few hours.* Experienced Dowell engineers do the job using Dowell pump trucks and control equipment.

Telephone Dowell today for consultation on your cleaning problem. No obligation, of course.

Other recent Dowell jobs:

Blast furnace gas washer cleaned in four hours without interrupting operation. Pressure differential was reduced from 24" to 3" of water.

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2,250 h.p. boiler cleaned for steel mill. Result: 12,000 lbs. per hour more steam on same amount of fuel. Dowell Service paid for itself in 11 days.

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Scale removed from ammonia liquor cooling coils. Increased revenue from by-product recovery, $153.25 per day.

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A SERVICE ORGANIZATION

Date-line Diary...

September 1

▲ The Sharon Steel Corp. announced that it is now making titanium sheets at its Niles Rolling Mill Co. plant.

September 2

▲ The Department of Commerce announced that employment in August was the greatest in history with a total number of 62,367,000 or 1,000,000 over July. Unemployment fell to 2,500,000.

▲ The price of lead advanced 1¢ a lb to 15¢ in New York.

▲ Sharon Steel Corp. announced that shipments in August were the greatest in history and 8 per cent over the previous high monthly record.

September 4

▲ Based on reports of companies having 94 per cent the capacity of the industry, the operating rate of the steel industry is scheduled at 98 per cent for the week beginning September 4. This is equivalent to 1,890,100 tons compared with 1,872,800 tons one week ago.

September 5

▲ The Ford Motor Co. boosted pay of most hourly rated employees 8¢ an hour.

▲ Under a new stockholders plan, steel rolling capacity of the Newport Steel Co. is expected to be expanded.

September 6

▲ Pennsylvania Railroad placed orders with a number of manufacturers for an additional 214 diesel locomotives whose estimated cost is $55,000,000. This supplements the order for 226 diesels let by the road last November.

September 7

▲ American Railway Car Institute announced that freight car orders in August totaled 24,280. New car deliveries were 5203 leaving a backlog as of September 1st of 86,156 compared with 28,731 one year ago.

▲ President Truman ordered a boost in the government's annual synthetic rubber production rate to 755,000 tons.

▲ The National Industrial Conference Board in a report stated that the spreading use of steel has proceeded even faster than the rapid decentralization of steelmaking in the United States during the past ten years.

September 8

▲ Zinc price was raised 2½¢ a lb to 17½¢ in East St. Louis.

▲ Because of copper shortages, the Copperweld Steel Co. curtailed operations and a number of the nation's largest brass mills reduced work schedules from six to five days a week.

▲ The Allegheny Ludlum Steel Corp. plans construction of a $2,500,000 electric melting division at its Watervliet, New York plant. Annual capacity will be 80,000 tons.

September 9

▲ Federal Reserve Board reinstalled consumer credit curbs to restrain inflation.

▲ Commerce Department reported that personal income jumped to an annual rate of $219,000,000,000 in July.

▲ According to Ward's automotive reports, automobile and truck output in the United States will top 6,000,000 units for the nine months ending September 30th.

September 10

▲ Charles R. Hook, chairman, Armco Steel Corp., stated that his company will spend $15,000,000 to modernize the Ashland, Kentucky plant. Plans include a modern slabbing mill and other equipment needed to produce a 72-in. wide coil.

September 11

▲ Commerce Department reimposed export controls on major iron and steel products.

▲ The Reliance Electric and Engineering Co. purchased a controlling interest in the Commonwealth Electric Co., Ltd. of Welland, Ontario.

▲ Based on reports of companies having 94 per cent of the steel capacity of the industry, the operating rate is scheduled at 99.6 per cent for the week beginning September 11, 1950. This is equivalent to 1,921,000 tons compared with 1,890,100 tons one week ago.

September 12

▲ Aluminum Association reported that United States aluminum industry is now producing primary metal at a rate of about 1,450,000,000 lb a year. This rate is more than 17 per cent greater than 1949 production. July production was 127,035,442 lb. Shipments of sheet and plate totaled 90,937,020 lb.

▲ E. R. Breech, vice president, Ford Motor Co., stated that they are currently spending $300,000,000 on new plants and equipment. Included in steel plant portion are new equipment to handle coils up to 66-in. wide weighing 50,000 lb, 12-new annealing furnaces, 9 radiant gas tube furnaces, conveyor equipment and temper mills.

▲ The Republic Steel Corp. announced that it will build a new boiler house and electric generating unit at its Youngstown, Ohio plant at an estimated cost of $7,000,000 to $10,000,000.

▲ Cleveland-Cliffs Iron Co. announced that it had ordered an 18,000-ton ore carrier and the Interlake Steamship Co. had also ordered an 18,000-ton carrier.

September 13

▲ Council of Economic Advisers reports that spending on new plant and equipment by business firms has increased markedly. Outlays at the end of the third quarter are at an annual rate of $20,240,000,000.

September 14

▲ F. W. Dodge Corp. announced that construction awards in the 37 states east of the Rockies hit an all time high in August with a total of $1,548,876,000.

▲ A government survey reports that business firms plan to spend $4,800,000,000 on new plant and equipment in the final quarter of 1950.

September 15

▲ A new radio station WEIR was opened in Weirton, W. Va. President of the Tri-State Broadcasting Co. is Thomas E. Millsop, who is also president of the Weirton Steel Co.

▲ A bill was sent to President Truman which will increase insurance coverage on bank deposits by the FDIC from $5000 to $10,000.

September 17

▲ The Washington Steel Corp. achieved the theoretical capacity goal of 1500 tons a month of stainless on its 36-in. sendzimir mill at Washington, Pa.

September 18

▲ Based on reports from companies having 94 per cent of steel capacity of the industry, the operating rate of the steel industry is scheduled at 100.4 per cent of capacity for the week beginning September 18, 1950. This is equivalent to 1,936,400 tons of steel compared with 1,921,000 tons one week ago.

▲ National Production Authority put inventory controls on 32 scarce items. Consumer credit curbs also went into effect today.

September 19

▲ Republic Steel Corp. and Armco Steel Corp. joined together on a $160,000,000 project to enlarge on the production of iron ore from taconite. Companies acquired 100 per cent ownership of Reserve Mining Co., which controls a big taconite deposit.

▲ Kaiser-Frazer announced price increases in cars of $10.00 to $120.00. Packard Motor Car Co. raised prices $81.00 to $112.00.

September 20

▲ Colorado Fuel & Iron Corp. purchased a 175 acre tract of undeveloped land adjacent to its Wickwire Spencer Steel Div. plant at Buffalo.

▲ The House of Commons by a vote of 306 to 300 defeated a resolution which would have been placed on record against putting Britain's steel industry under nationalized control on January 1, 1951.

▲ ALCOA volunteered a general wage increase of 10¢ to its hourly paid employees.

September 23

▲ ALCOA raised aluminum prices 1½¢ to 18¢ for pig and 19¢ for ingots.

▲ Carnegie-Illinois Steel Corp. will put its No. 3 blast furnace at Clairton in production today. The furnace has been shut down for 72 days and is producing ferro-manganese.

September 24

▲ The Alabama By-Products Corp. awarded the Koppers Co. a contract to build 29 new coke ovens at Tarrant, Ala.

▲ The Ohio River Steel Corp. purchased the Toronto, Ohio plant of the Follansbee Steel Corp. for about $500,000 and expects to make steel in 60 days.

September 25

▲ Based on reports from companies having 94 per cent of the steel capacity of the industry, the operating rate for the week beginning September 25 is scheduled at 100.7 per cent of capacity. This is equivalent to 1,942,200 tons compared with 1,936,400 tons one week ago. This is the largest amount of steel ever to be made in one week.

▲ Estimated can production for the first half of 1950 increased about 1,500,000,000 units over 1949 with an equivalent figure of about 12,880,000,000 No. 2 cans.

▲ Commerce Secretary Sawyer stated that there is no doubt that new economic controls will be imposed on business which will probably include priority and limitation controls.

▲ Republic Steel, Youngstown Sheet & Tube and Interlake Iron Corp. raised pig iron prices $3.00 a ton to $49.00 for basic iron.

▲ World production of tin in July was estimated at 13,500 long tons compared with 15,100 tons in June.

September 26

▲ The Inland Steel Co. turned down a request by the Steel Workers for an early reopening wage increase talk.

September 27

▲ Treasury Secretary Snyder stated that taxes will go up substantially no matter what happens in Korea.

▲ Phelps Dodge Corp. raised copper price 2¢ to 24½¢ a lb. Kennecott is still holding the price at 22½¢ a lb.

▲ The AISC reported that August bookings of structural steel totaled 250,910 tons compared with 98,953 tons for the same month in 1949. August shipments totaled 173,053 tons (highest this year) compared with 183,868 tons one year ago. The backlog for the next four months increased to 741,301 tons.

September 28

▲ The Wheeling Steel Corp. declared a 25 per cent stock dividend on the common stock.

▲ Geneva Steel Co. awarded to Koppers Co. a contract for a battery of 23 coke ovens at its Ironton plant. This battery will have a carbonizing capacity of 600 net tons of coal per day.

▲ The share holders of the Youngstown Sheet and Tube Co. voted today to split the company's common shares two for one.

▲ Freight loadings last week were the greatest in almost two years with 870,196 cars.

September 29

▲ Kaiser Steel Corp. started a $125,000,000 financing program today. Program consists of $60,000,000 first mortgage, 3¾ per cent bonds due 1970, $25,000,000 bank credit, and $40,000,000 through sale of 1,600,000 shares preferred and 800,000 shares common stock. Money will be used for repayment of $91,000,000 RFC loan, about $24,500,000 will be used for an expansion program which will include facilities for annual production of 200,000 tons of hot dipped and electrolytic tin plate, an additional 200-ton open hearth, soaking pits and blooming facilities. The remaining money will be used for additional working capital.

▲ Benjamin F. Fairless announced that an additional 500,000 tons of ingot capacity will be added to TCI & RR Co.

September 30

▲ The Sharon Steel Corp. raised steel prices about 5 per cent. Increases range from $5.00 to $10.00 a ton.

▲ Commerce Department reported that unemployment fell in September to the lowest level in 21 months with an estimate of 2,341,000. Total employment in September was 61,226,000.

▲ Commerce Department reported that sales in August set a new record with $24,000,000,000. New orders rose to $27,800,000,000.

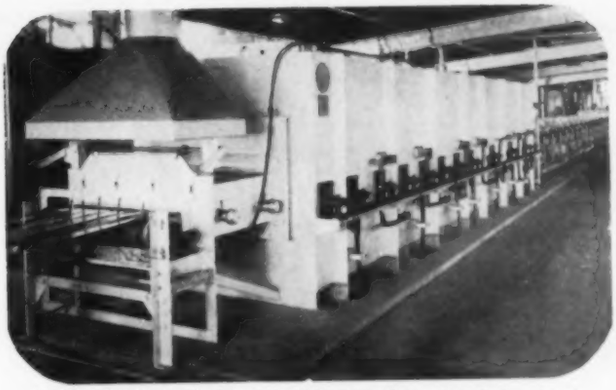
▲ The NPA announced that synthetic rubber allocations will be based on consumption during the 12 months ending last June 30.

September 30

▲ Atlas Steels, Ltd., will install a cold mill for stainless steel sheet.

▲ The Allegheny Ludlum Steel Corp. acquired a 35 per cent interest in Continuous Metalcast Corp. This latter corporation owns rights to a continuous casting process and its business will primarily be to license others to use its processes.

Steel strip in single or multiple strands up to a total width of 54" may be bright annealed or normalized, continuously, in this EF gas fired radiant tube installation. Capacity 7200 lbs per hour.

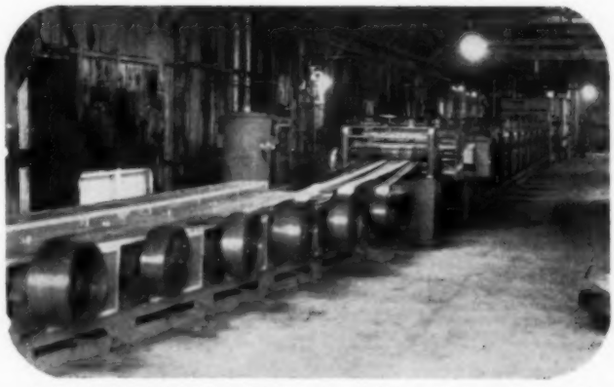


An EF electrically heated special atmosphere installation bright annealing six parallel strands of cold rolled steel strip, continuously. Handles single or multiple strands up to a total width of 30".

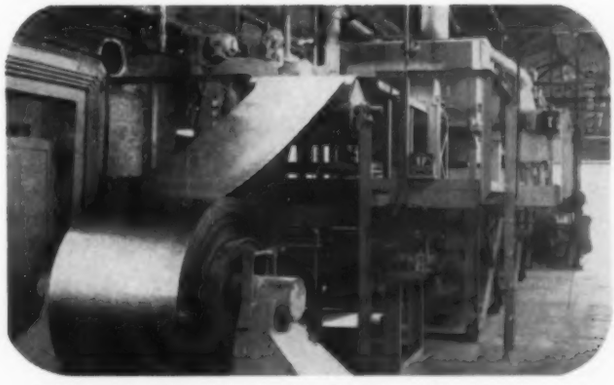
SOME TYPICAL EF INSTALLATIONS

For Processing Strip

Displayed at the Recent AISE Exposition



Another EF gas fired radiant tube, continuous furnace for bright annealing or normalizing cold rolled strip steel. Has preheater or burn-off chamber and handles 2000 lbs strip per hour.



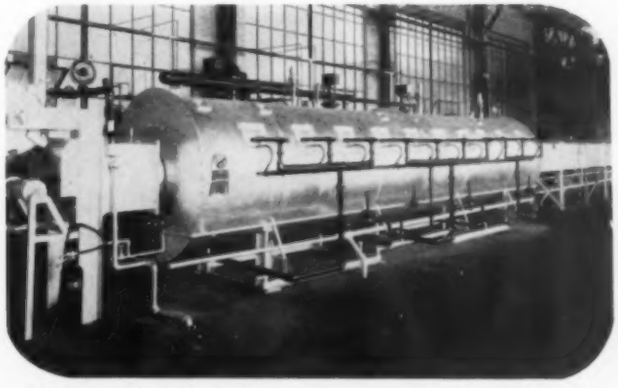
An EF special atmosphere furnace with flame preheating burn-off or oxidizing section, and controlled heating and cooling zones for producing various surface conditions on strip steel.

Designed and Built by

The Electric Furnace Co., Salem, Ohio

Gas Fired, Oil Fired and Electric Furnaces—For Any Process Product or Production

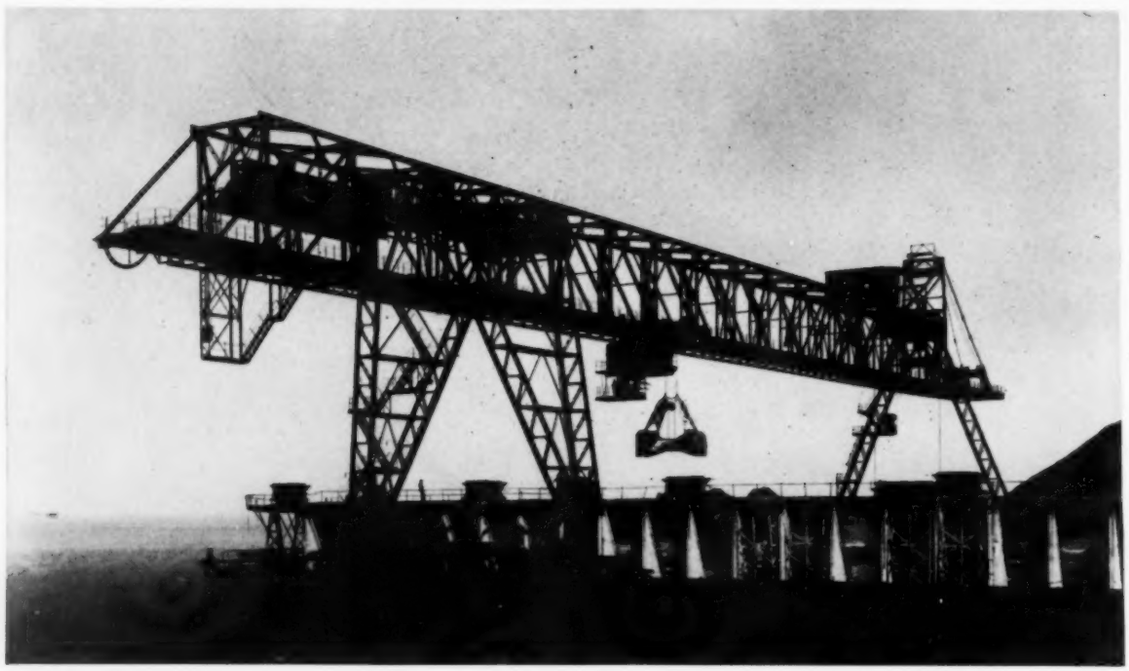
This EF combination fuel fired and electrically heated strip processing unit provides extreme flexibility in heating, soaking and controlled cooling cycles for treating various grades of strip.



Stainless steel strip is bright or process annealed continuously in this EF gas fired special atmosphere tube muffle type furnace. It also handles other strip requiring lower temperatures.

Another H&P COAL BRIDGE

Recently Placed in Operation
In One of the World's Largest Steel Plants



THIS New Coal Bridge, designed, fabricated and erected by Heyl & Patterson is one of the largest Coal Bridges ever built. ***It contains many of the Modern Coal Bridge features described in this issue of Iron & Steel Engineer.***

Read the Paper prepared by B. A. Rose, Director of Engineering for Heyl and Patterson.

During the design period of this coal bridge the engineers and maintenance supervisors of the client collaborated with the engineers of Heyl & Patterson. The result is maximum accessibility to all places and maximum ease of maintenance for all parts of the bridge.

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Railroad Car Dumpers
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Boat Loaders and Unloaders
Rotary Mine Car Dumpers
Coal Crushers
Coal Storage Bridges
Car Hauls & Boat Movers
Bradford Breakers
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WHITCOMB *Hydro Motive*

Whitcomb 25-Ton Diesel Hydro-Motive Locomotive handles a train of hot metal ladles at the open hearth of Crucible Steel Company of America.

MEANS . . .

- **LOWER MAINTENANCE COSTS**
- **LONGER LOCOMOTIVE LIFE**
- **EASIER OPERATION**
- **SMOOTHER HANDLING**

MOVES MORE MATERIALS, LONGER, FOR LESS

The Whitcomb Hydro-Motives give you greater value *every* way. You get the smooth-flowing power of an electric drive at far less cost with a Whitcomb Hydro-Motive. And maintenance costs are lower, too, because wearing, jarring road bed shocks are *not* transmitted to the engine. Instead the jolts are absorbed in the fluid coupling of Whitcomb's Hydro-Motive. Thus, locomotive wear is cut down, locomotive life lengthened.

But economy is only one advantage of the Whitcomb Hydro-Motives. They reduce operator-fatigue, reduce accident risks, because there is no lunging, no shifting — power is smooth, instant, uniform at any speed.

And the Hydro-Motive locomotive is every inch a Whitcomb — which means the finest in engineering, in materials, in workmanship. Replace your present outdated locomotives with smooth, new Whitcomb Hydro-Motives.

Write today for complete information on Whitcomb Hydro-Motive Locomotives, in sizes from 10 to 40 tons.

Whitcomb Locomotive pushes a charge of timbers into creosote cylinder at American Lumber & Treating Company's Everett, Washington plant.

At the new Noralyn phosphate mine near Bartow, Fla., a Whitcomb Diesel does 24-hour duty.

There is no power cheaper than Diesel; no locomotive finer than a Whitcomb locomotive.

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Single reduction, horizontal.
Capacities to 250 hp; reductions to 100: 1.
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Herringbone Gear Reducers

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Handy tables, curves and formulaes for determining stresses, torques, bending moments and deflections in steel shafts.

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DE LAVAL

WG-28

The Morgan-Isley System or Conventional Natural Draft?

Which will recover the most heat?

Which will save the most fuel?

Which has no leaky reversing valves?

Which produces unlimited draft—regulated with extreme accuracy?

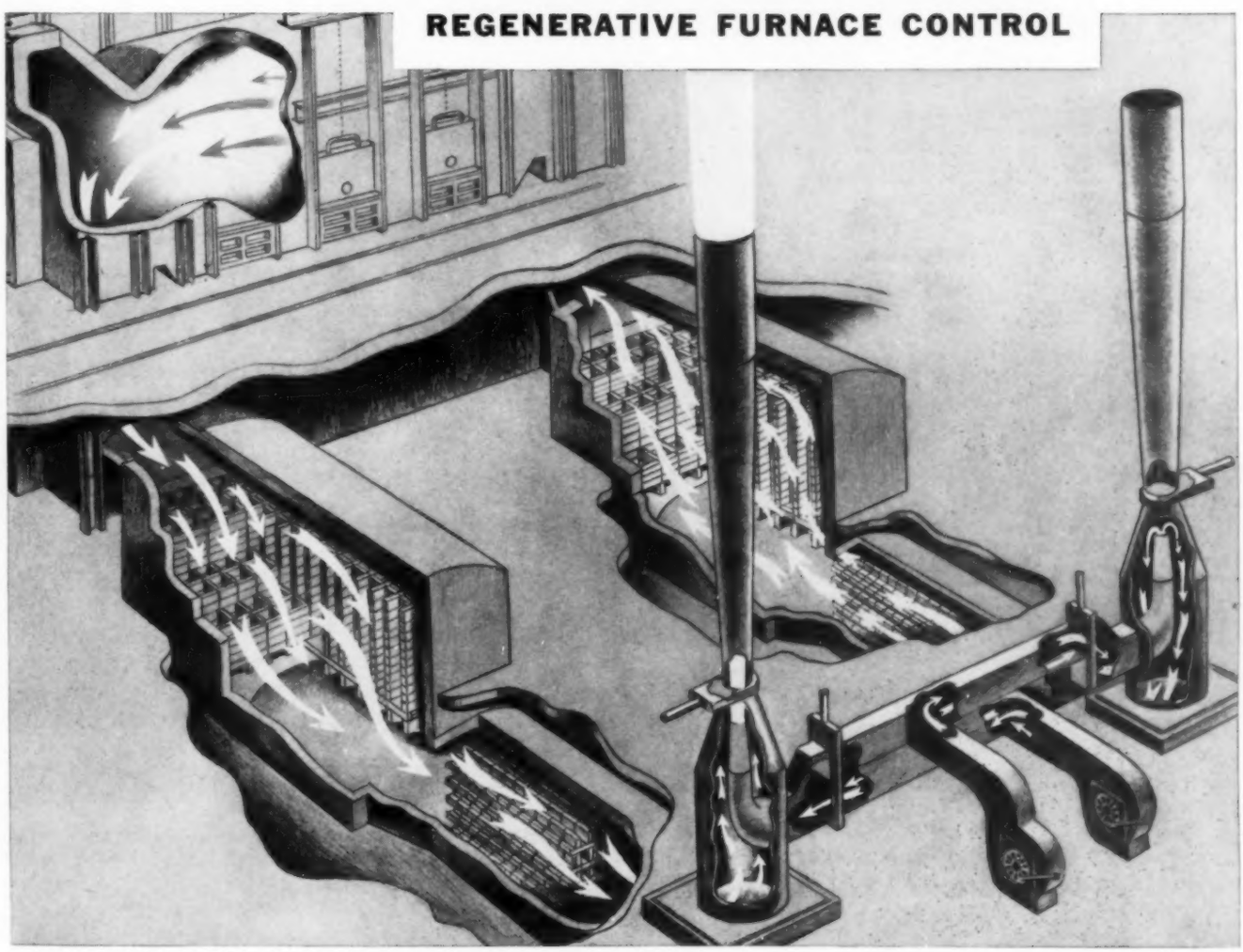
Which costs less to buy and erect—a Morgan-Isley System or water-cooled reversing valves, dampers and a natural draft stack?

The Morgan-Isley System is the answer to these and your other questions regarding combustion control.

Let us explain more fully.

MORGAN-ISLEY

REGENERATIVE FURNACE CONTROL



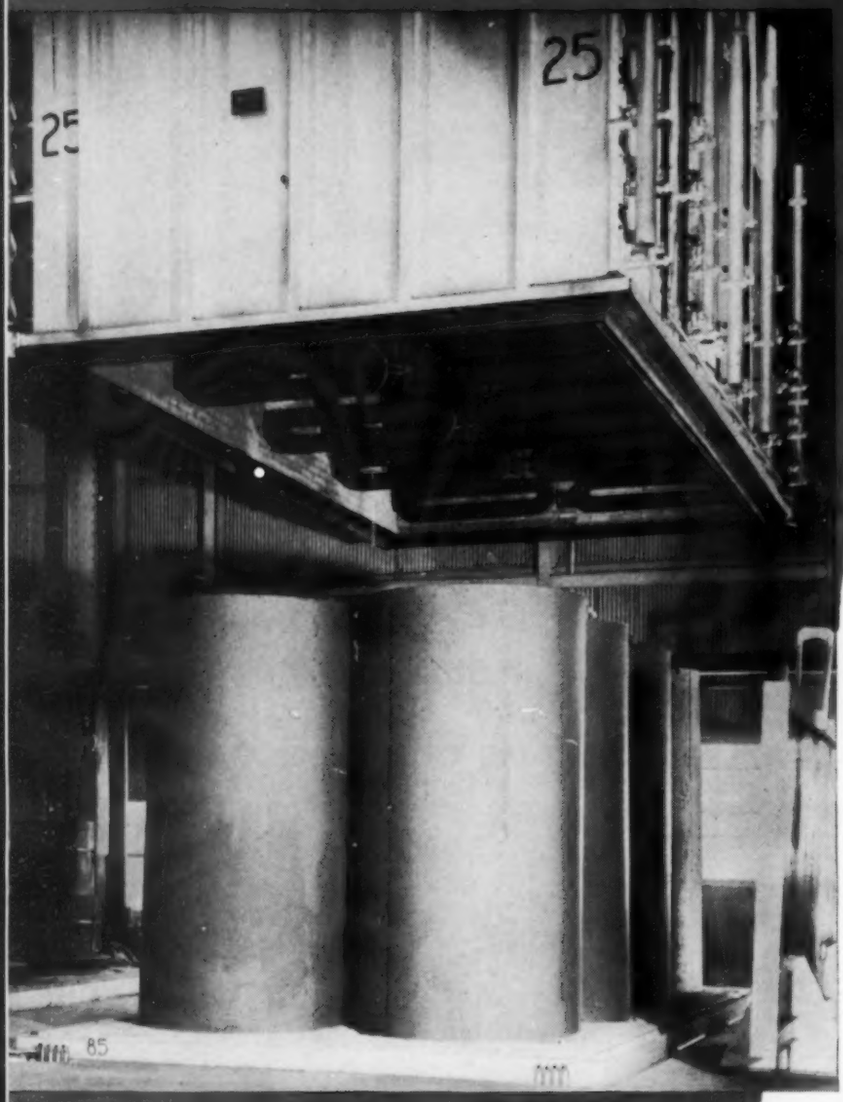
Morgan Construction Company

WORCESTER, MASSACHUSETTS

PITTSBURGH, PA., 2815 Koppers Building

English Rep., International Construction Co., 56 Kingsway, London W.C. 2, Eng.

CCC-25



Leadership at work!

ONE of **16 COIL FURNACES** installed in a large Midwestern plant—

plus

10 FLAT SHEET FURNACES installed at the same time

SWINDELL-DRESSLER

RECIRCULATING RADIANT TUBE

In this large Swindell-Dressler installation, each 40-tube furnace is capable of annealing eight stacks per base of sheet steel in 72" O.D. diameter coils, stacked 150" high —aggregating 600 tons of metal per heat.

Let a Swindell-Dressler Engineer consult with you regarding your particular furnace requirements—on any scale, anywhere.

SHEET ANNEALING FURNACES

SWINDELL-DRESSLER Corporation

DESIGNERS AND BUILDERS OF MODERN INDUSTRIAL FURNACES

PITTSBURGH 30, PA.

REDUCE PRODUCTION STOPPAGES

due to harmful atmospheres

UNIT-COOLED

D-C MOTORS

from 15 to 200 hp

Single-blower type for normal speed operation In this standard G-E motor, the unit cooler consists of alternate air passages placed at right angles to each other. Clean motor air, kept in motion by a fan on the main motor shaft, circulates through one set of passages in an enclosed system. Cool outside air, drawn into the cooler by a blower separately motor-driven, flows through another set of passages and absorbs the heat from the internal air stream. Motor air, never in contact with contaminated outside air, is always clean.

Reliable Performance . . . dust, dirt, dampness, metal particles, or oily vapors can't affect the operation of these General Electric standard, totally-enclosed, unit-cooled d-c motors.

Fewer Inspection Shutdowns . . . windings, brushes, and brush rigging are kept clean at all times because motor air never comes in contact with contaminated outside air.

Reduce Power Cost . . . because motor heat is rapidly dissipated, power consumption is less, especially in wide-range adjustable-speed motors.

Simplify Maintenance . . . large openings in the commutator end shield make it easy to get at commutator, brushes, and brush rigging.

Save Mounting Time . . . interchange of motors to meet changing plant conditions takes less time because G-E totally-enclosed motors have the same mounting dimensions as G-E open motors of the same ratings.

Get The Whole Story . . . ask your G-E representative how these sturdy, protected motors can increase production and trim operating costs in your plant, or send for Bulletin GEA-4469. *Apparatus Dept., General Electric Company, Schenectady 5, N. Y.*

Double-blower type for continuous low speeds New—a totally enclosed standard G-E motor that can't run a fever! Without danger of overheating, it delivers full torque continuously, even at very low speeds. Key to its operation is a new development—ventilation entirely independent of motor speed. Two blowers, mounted on opposite shaft extensions of a single auxiliary motor running at constant speed, provide full ventilation at all times. One circulates internal air and the other external air through alternate vertical passages.

GENERAL ELECTRIC

770-23

Is MOISTURE your magnet problem?

Here's an Ohio lifting magnet that operates underwater 50 percent of the time, retrieving hot crop-ends from a cooling pit. It is a standard Ohio bolted-type magnet which has not been waterproofed in any way!

This unusual application proves the extra margin of moisture protection built into every Ohio Magnet.

For longer magnet life and greater dependability, why not send your next order to Ohio—*25 years a leader in magnetic materials handling.*

Remember this picture next time you buy!

SELECT YOUR MAGNET from two Ohio types. The PROTECTO-WELD magnet, shown here, is made in 39, 46, 55 and 65-inch diameters. Bolted construction types include these and other smaller sizes.

THE OHIO ELECTRIC MFG. CO. • 5900 MAURICE AVENUE • CLEVELAND 4, OHIO

ohio MAGNETS

A-1924

Industry News...

U. S. STEEL ANNOUNCES THREE IMPORTANT EXPANSION PROGRAMS

▲ Benjamin F. Fairless, president of United States Steel Corp., made the following statement on September 29:

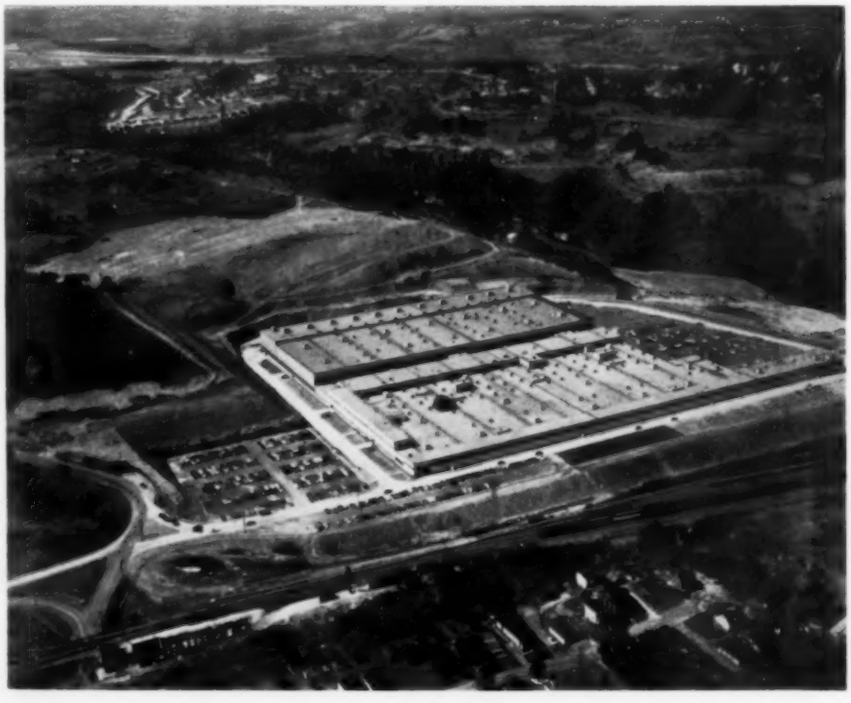
"Substantial increases in the demand for steel following the invasion of Korea last June, and the resulting revision of the nation's defense plans, have caused United States Steel to give serious consideration to the manner in which its own steel capacity can most expeditiously be enlarged to meet the needs of the present national emergency.

"Last July, United States Steel announced the first step in such a program to obtain additional steel production. This is to be accomplished through improvement and additions to existing facilities in the Pittsburgh and Chicago district, which will result in an increase of 1,660,000 tons in the annual steelmaking capacity of United States Steel by the end of 1951. This step is presently under way.

"The second step in this program, which, upon its completion, will add 500,000 tons of further ingot capacity annually. Under this second step, the annual ingot capacity of Tennessee Coal, Iron and Railroad Co., U. S. Steel subsidiary at Birmingham, Ala., will be increased from 2,850,000 tons to 3,350,000 tons. It is expected that this additional capacity can be made available within 18 to 24 months after the commencement of the work.

"The building of an eastern seaboard steel mill on the banks of the Delaware River near Morrisville, Pa., will constitute the third step in this program. How large that plant will be, and what kinds and quantities of finished products will be made there, has not yet been determined, as that will depend upon the defense and military needs of this country."

AERIAL VIEW OF FISHER'S PITTSBURGH PLANT



Shown is an aerial view of General Motors' new Pittsburgh plant, a unit of the Fisher body division. The plant produces dies and body stampings for the five General Motors car divisions. The plant occupies a 68-acre site on Lebanon School Road in West Mifflin Borough. It consists of one large building with a roof area of 14.6 acres and contains 800,000 sq ft of space. The building is of steel structure enclosed with yellow face brick and steel sash in the general office area, as well as the north end of the building. Balance of the building is enclosed with concrete block, steel sash and corrugated transite siding. The roof consists of steel decking covered with fiberglass insulation. The plant floor and production area is of wood block laid on concrete. The office area floors are of reinforced concrete covered with asphalt tile.

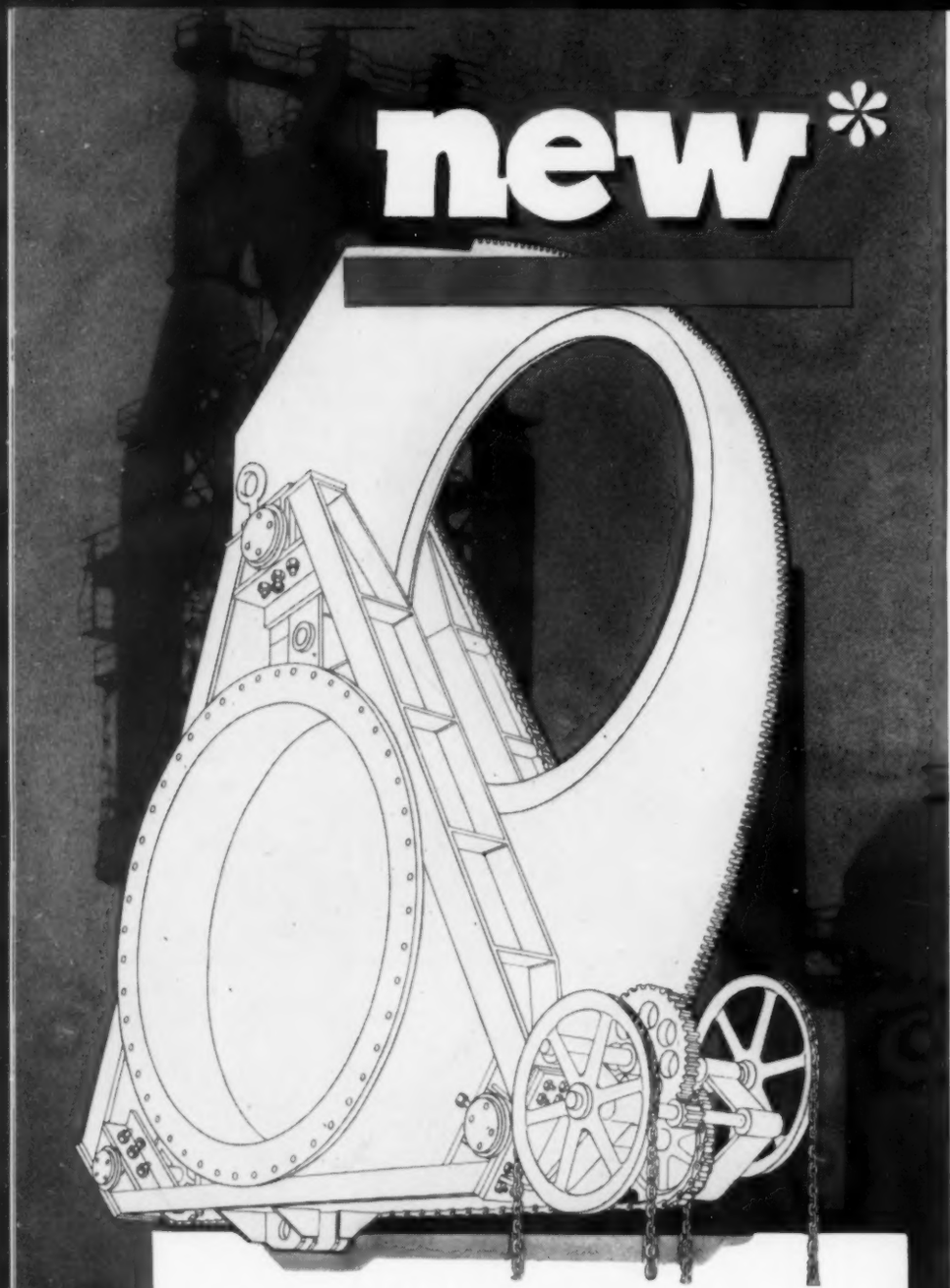
AETNA-STANDARD EXPANDS AT ELLWOOD CITY, PA.

▲ Aetna-Standard Engineering Co., Youngstown, Ohio, has announced a new expansion program, and transference of offices and personnel from Youngstown, Ohio, to Ellwood City, Pa., during the summer of 1951. This will effect approximately 153 families presently living in Youngstown. All business currently conducted in Youngstown will then be carried on in Ellwood City, save for executive management and sales operations. Some twenty Aetna-Standard families will move to Pittsburgh where management and sales activities will be conducted in closer proximity to many of Aetna's customers.

Office space in Youngstown will be relinquished and new offices set up in an Ellwood City building formerly owned by the National Tube Co. It will soon undergo extensive remodeling.

Announced also is a second important move, Aetna's entry into the rubber and plastic industries through association with Hale & Kullgren, Inc., Akron, Ohio, rubber and plastic machinery consultants.

In the past, Aetna's Warren, Ohio, plant built most of the company's flat rolled finishing equipment. Now, the Warren plant assumes greater importance in that it will build rubber and plastic industry equipment to specifications furnished by the Akron firm. Aetna does not intend to have its Warren plant build existing types of machinery, such as mills, calendars, etc., but will erect more or less revolutionary types of equipment built to satisfy current needs of the two industries mentioned. In addition to pioneering work, the Warren plant will also do considerable work in rebuilding Banbury mixers.



Brosius-Westling

Goggle Valve

* This complete redesign of a time-tested valve now gives you fastest positive mechanical operation combined with high structural strength and new protection against leakage. Your inquiry is invited.

Edgar E. BROSIUS Company Inc.

SHARPSBURG - PITTSBURGH 15, PA.

"OFF-THE-RECORD" AIME MEETING SCHEDULED

The 5th annual "off-the-record" meeting of the Pittsburgh section of AIME will be held in William Penn Hotel, Pittsburgh, Pa., November 3. The Pittsburgh section of the National Open Hearth Committee will hold its meetings concurrently with the Coal, Petroleum and Institute of Metals division.

General program chairman is R. S. Moore, manager of basic sales, Harbison-Walker Refractories Co.

CHILEAN STEEL FIRM NAMES PURCHASING AGENTS

▲ Chile's newest steel mill, located at Huachipato, Chile, and operated by the Compania de Acero del Pacifico, has named Pacific International Corp. as its purchasing agents in the U. S. and Canada, it was announced by G. E. Alvarado, vice-president of Pacific International.

The mill, only recently completed, is already in production, and has filled several orders from Chile and neighboring countries. Previous U. S. purchasing has been handled by Corporation de Fomento de la Produccion de Chile, a governmental purchasing organization. The appointment of the new agents does not affect any outstanding orders from Fomento, nor does it preclude the possibility of Fomento's placing of new orders.

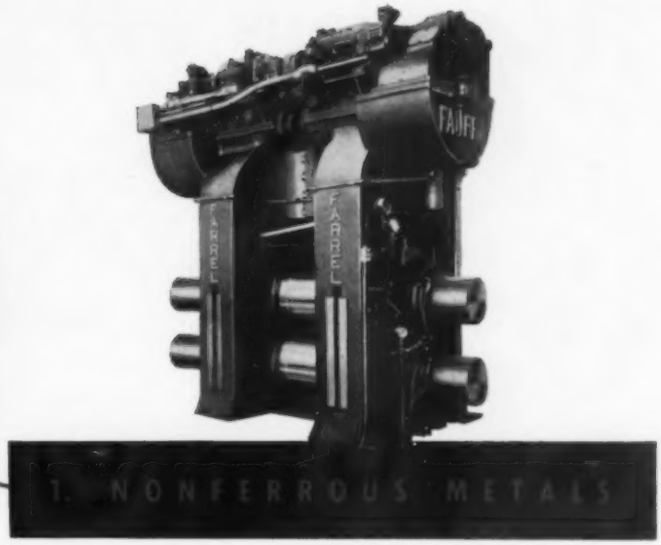
Pacific International Corp., an import-export organization, has offices at 42 Broadway, New York, and representation in many Latin American and European cities.

NEW STEEL COMPANY BUYS TORONTO, OHIO, WORKS

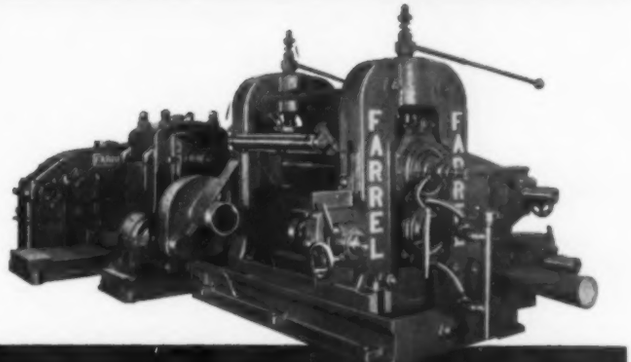
▲ Ohio River Steel Corp., recently formed to purchase, rehabilitate and modernize steel plants, has acquired the works at Toronto, Ohio, formerly owned by Follansbee Steel Corp., according to an announcement by Samuel E. Magid, chairman of Ohio River Steel Corp. The transaction was arranged by Hill, Thompson & Co., Inc., New York City investment bankers.

Mr. Magid, who is also chairman of Penn-Ohio Steel Corp., said that

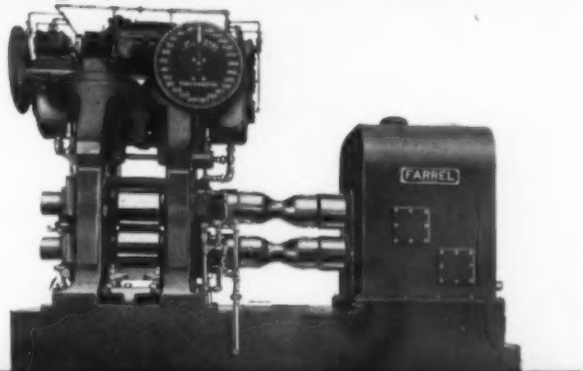
FARREL® MILLS FOR ROLLING



1. NONFERROUS METALS



2. METAL FOILS



3. COLD STRIP STEEL

For almost a century, Farrel mills have been helping to solve rolling mill production problems. Designed to meet specific requirements, they are built in a wide range of types and sizes for rolling nonferrous rods, strips or sheets, metal foils and cold strip steel.

The company also designs and manufactures the reduction gear drives and pinion stands, coilers and special handling equipment required to make each installation a complete unit.

Farrel engineers are prepared to design mills for the solution of your production problems. Write for quotations on mills for specific applications.

FARREL-BIRMINGHAM COMPANY, INC.
ANSONIA, CONNECTICUT
Plants: Ansonia and Derby, Conn., Buffalo, N. Y.
Sales Offices: Ansonia, Buffalo, New York, Akron, Pittsburgh, Chicago, Los Angeles, Houston

For preliminary information about rolling mills to suit your particular requirements, please furnish the following details:

Kind of metal . . . daily production . . . hot or cold rolling . . . starting thickness and final gauge . . . maximum and minimum width . . . method of handling during rolling . . . alternating or direct current.

1. 28" x 30" two-high cold brass running-down mill, with double motor screwdown.

2. 14" x 42" two-high double let-off foil mill, with wind-up, wiper attachments and ironing roll.

3. 10" x 10" two-high reversing cold strip mill, with single reduction drive and pinion stand mounted on common base with mill.

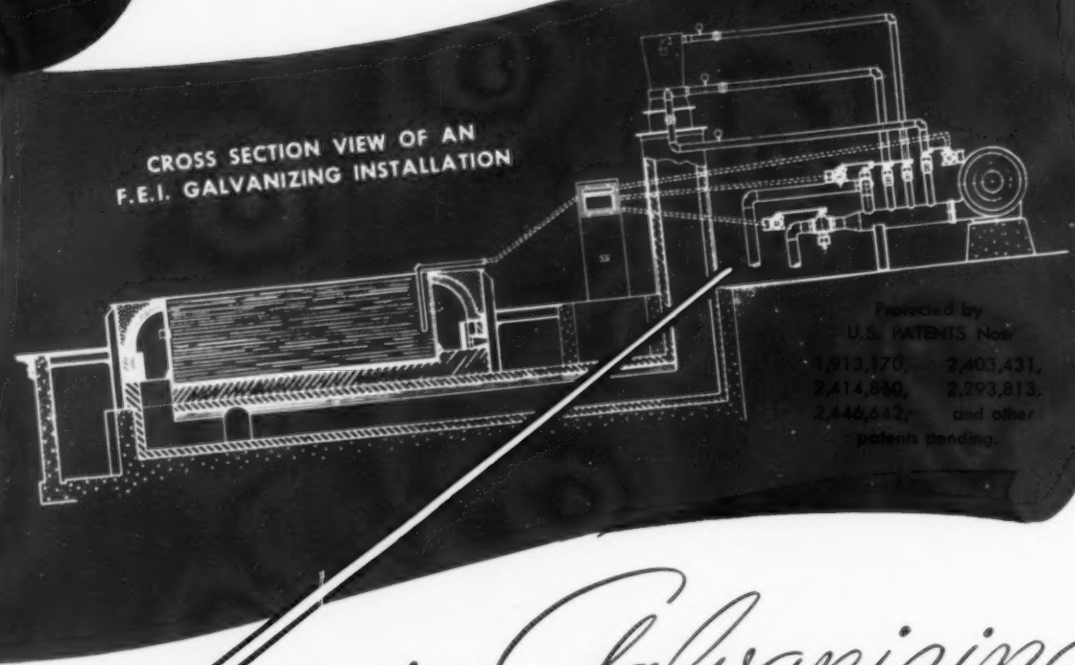
FB-582

Farrel-Birmingham®
Established 1836

3 REASONS WHY

F·E·I controllable exhaust system

IMPROVES PERFORMANCE



...in Galvanizing

SHEETS—TUBES—METALWARE

SPEEDS UP PRODUCTION! *Automatic OPERATING CONTROL* regulates heat input and exhaust simultaneously . . . The required temperature is reached *faster!*

SAVES FUEL! *Automatic HOLDING CONTROL* holds uniform temperature on *minimum gas flow,* after the desired operating temperature has been reached. Cuts cost of production.

PROLONGS KETTLE LIFE! *Automatic LIMITING CONTROL* limits temperature during periods of low heat requirement and sudden shutdowns. Actual records show kettle life more than doubled or even tripled. Get all the facts . . . how the F.E.I. Controllable Exhaust System has really modernized galvanizing technique.

Write for Bulletin

F E I *Furnace Engineers, Inc.*

F. E. I. Building • 1551 West Liberty Avenue • Pittsburgh 16, Pa.

3

steel is expected to be poured at the Toronto plant within 60 days. The plant has four basic open-hearth furnaces with an annual capacity in excess of 186,000 net tons, and a bar mill with a capacity of 125,000 tons a year. Plans are underway for the installation of rolling equipment.

REPUBLIC AND ARMCO JOIN IN ORE PROJECT

▲ Republic Steel Corp. and Armco Steel Corp. have joined in a $160 million project for the production of iron ore from taconite in the Lake Superior mining region.

The two companies announced acquisition in equal shares of 100 per cent ownership of the stock of Reserve Mining Co. which controls a vast deposit of magnetic taconite iron ore at the western end of the Mesabi Range in Minnesota's St. Louis County.

Through Reserve Mining, the two steel companies will build a plant for manufacturing high grade ore from the low iron content taconite near Beaver Bay, on the north shore of Lake Superior. The first unit, costing about $60 million, will be built as soon as plans are completed and will have an annual capacity of 2,500,000 tons of iron ore pellets. Longer range development plans call for future expansion of the plant to provide an annual capacity of 10 million tons, at an additional cost of $100 million.

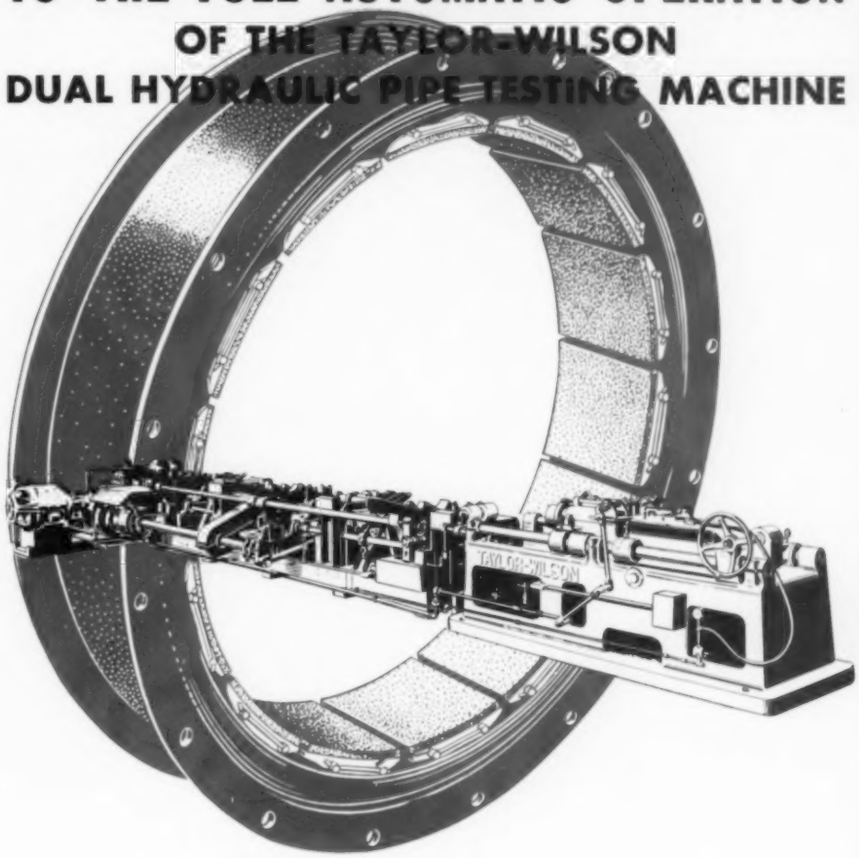
INLAND STARTS NEW COKE OVEN BATTERY

▲ Inland Steel Co. recently put into operation its new battery of 65 coke ovens at its Indiana Harbor, Ind., plant. With the charging of coal into the ovens the steel company lifted by 200 tons daily its capacity to produce coke which is essential in the making of steel. Increased production of by-products including tar, toluol, benzol, and naphtha used in drugs, flavoring, dyes, and explosives will also result.

The new coke oven battery which will bake 980 tons of coke daily from more than 1500 tons of coal will replace one built in 1914 that is being taken out of production for future rebuilding. The plant will have in operation a total of 414 ovens after the withdrawal of the old battery.

Under construction for more than a year, the new ovens were first fired

Fawick Clutch and Brake Contribute TO THE FULL AUTOMATIC OPERATION OF THE TAYLOR-WILSON DUAL HYDRAULIC PIPE TESTING MACHINE



Fawick Airflex 28CB525 Clutch and 27E475 Brake units play an important part in the high-speed operation of the new Taylor-Wilson automatic hydraulic pipe testing machine.

Exclusive Fawick design and operating features provide these modern machines with:

INSTANT RESPONSE — The "direct" action of air pressure on the operating tube and friction shoes makes Fawick Clutch or Brake action *instantaneous* —no action or power "detours" through mechanical linkages.

FULL POWER—The 360° radial contact of Fawick friction shoes at the maximum diameter results in the greatest torque and FULL POWER operation.

SHOCK-FREE OPERATION — Clutch operating torque is transmitted through the flexible rubber tube, dampening shaft vibrations and cushioning peak load shocks.

Add to these the Fawick advantages of overload protection at a selected air pressure, greater operator safety, and unparalleled low maintenance, and you have the component operating factors for top-efficiency production on your machines—making good machines even better.

For specific information on all advantages of Fawick Industrial Clutch and Brake Units, write to the Main Office, Cleveland, Ohio, for Bulletin 300.

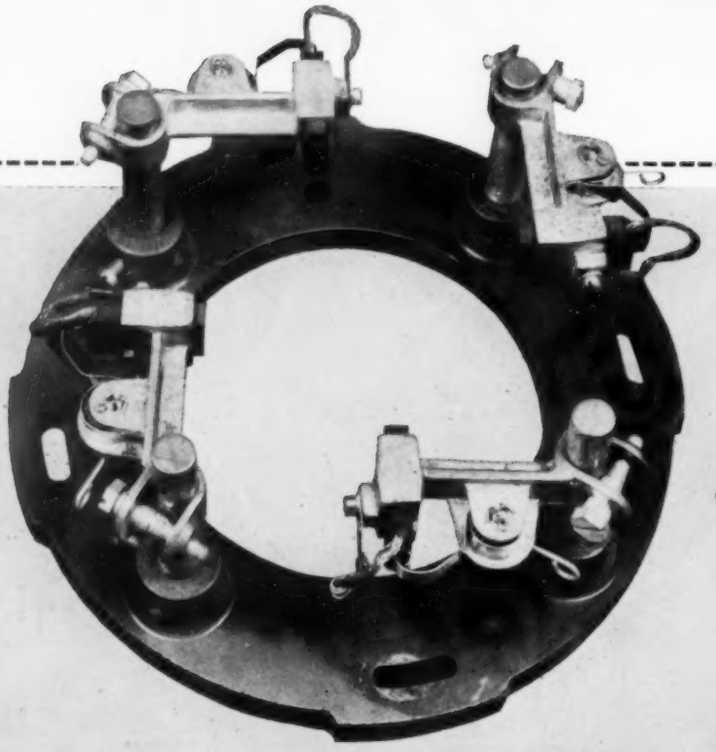
All desirable clutch characteristics are built into Fawick Airflex units

FAWICK Airflex CO., INC.
9919 CLINTON ROAD CLEVELAND 11, OHIO

FAWICK CLUTCHES = AXIAL CONTACT + 360° RADIAL CONTACT + SHOCK ABSORPTION + CONTROLLED TORQUE = PEAK EFFICIENCY

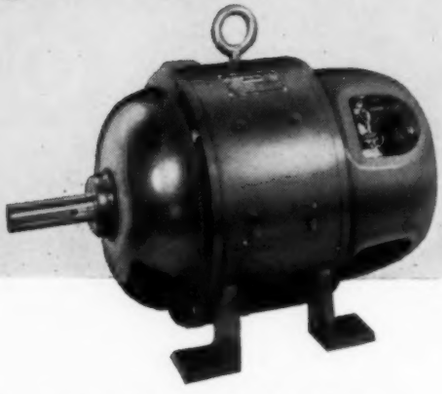
YOU CAN BE **SURE**.. IF IT'S

Westinghouse



Something ***NEW*** *has been added to...*

SK DEPENDABILITY



Arcs leave no tracks on this *MELAMINE* ring

When conducting dust collects across the surface of a rocker ring, it can cause a flashover. In the case of ordinary materials used for rings, this arc carbonizes a path into the ring itself. Thus, when the machine is cleaned to remove conductive particles, the path or track cannot be removed. High resistance grounds result. Motor efficiency is lost.

But, carbon flashovers don't have a chance on this Melamine ring. It's arc proof... noncarbonizing. There is no tracking effect ... no "burned-in" paths to cause shorts. Thus, when you wipe the ring clean, it is restored to full service condition. Top motor efficiency is maintained.

That is one reason why the Life-Line SK offers users of d-c motors new dependability. Cast brass brushholders are another. They are noncorroding ... have no bearings to wear or bind. No moving parts to get out of adjustment. A stainless steel spring maintains perfect brush contact through constant tension.

There are other reasons, too. Ask your Westinghouse representative to show you the inside story of the Life-Line SK motor. See the "Transvision" presentation. It takes the SK apart and puts it together again at your own desk. You'll see why something new has been added to SK dependability. Call your local representative today. Westinghouse Electric Corporation, P. O. Box 868, Pittsburgh 30, Penna. J-21555

Westinghouse

Life-Line

D-C Motors

on June 1 and in the intervening three and one-half months temperatures have been brought up gradually to the 2500-2700 F required for coking.

ISABELLA FURNACE TO BE REBUILT

▲ Carnegie-Illinois Steel Corp. has announced that blast furnace No. 3 at Isabella Furnaces, Etna, Pa., will be rebuilt for the production of ferromanganese. Officials of the U. S. Steel subsidiary said that the decision was made to aid in the government's defense program and is a temporary measure.

Rebuilding the Isabella stack, which has been idle for over a year, will permit production of pig iron at one of the company's Monongahela Valley blast furnaces, which otherwise would be scheduled to produce ferromanganese. The rebuilding job will commence immediately and the furnace is expected to be placed in operation by the end of this year.

ARMCO EXPANDS AT ZANESVILLE, OHIO, WORKS

▲ Chemical Plants division of Blaw-Knox Co. has received a contract from the Armco Steel Corp. for the construction of building additions in the steel producer's Zanesville, Ohio, plant.

The hot mill building will have an addition of 100 by 260 ft, and the annealing building will have an addition of 87 by 108 ft, both additions to be one-story construction.

OFFERS MONTH'S PAY FOR MILITARY SERVICE

▲ Westinghouse Electric Corp. employes who have been with the firm for more than one year will receive a month's extra pay if they enter the armed services while active conflict continues.

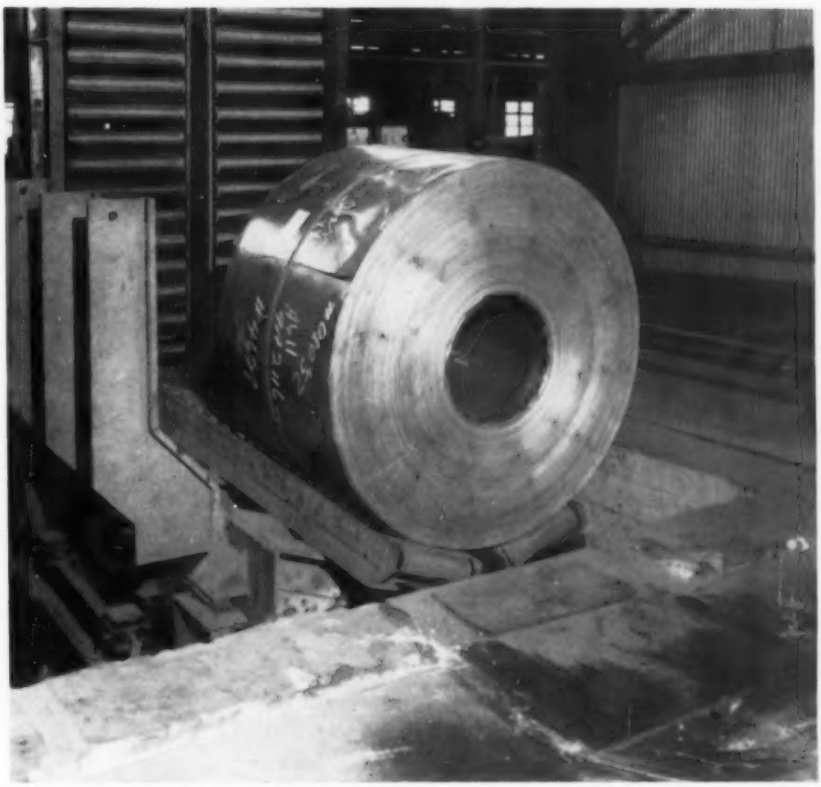
This policy, retroactive to July 1, was announced by Tom Turner, vice president in charge of plant labor relations in Pittsburgh. The Company also will pay group life insurance premiums for a period of three months for those entering military service.

The same re-employment rights as those which applied for World War II veterans also have been put into effect, he said.

In addition to the extra month's

Cartons or Coils

OUNCES OR TONS



handling it is a MATHEWS job

▶ With sound engineering practices and quality materials, Mathews builds fine, versatile material handling equipment . . . systems capable of meeting any conveying requirement for handling any package . . . from a twenty-five ton coil to a one pound carton.

When you install a Mathews Conveyer system in your plant, you get technical experience in a product built to withstand years of rugged punishment, PLUS a seasoned engineering staff, willing and able to assist you in the solution of your conveying problems.

Engineering offices located in principle American and Canadian cities.

●

MATHEWS CONVEYERS

GENERAL OFFICES . . . . . *Mathews Conveyer Company*
ELLWOOD CITY, PENNSYLVANIA

PACIFIC COAST DIVISION . . *Mathews Conveyer Company West Coast*
SAN CARLOS, CALIFORNIA

CANADIAN DIVISION . . . . . *Mathews Conveyer Company, Ltd.*
PORT HOPE, ONTARIO

CENTERLESS BAR TURNER

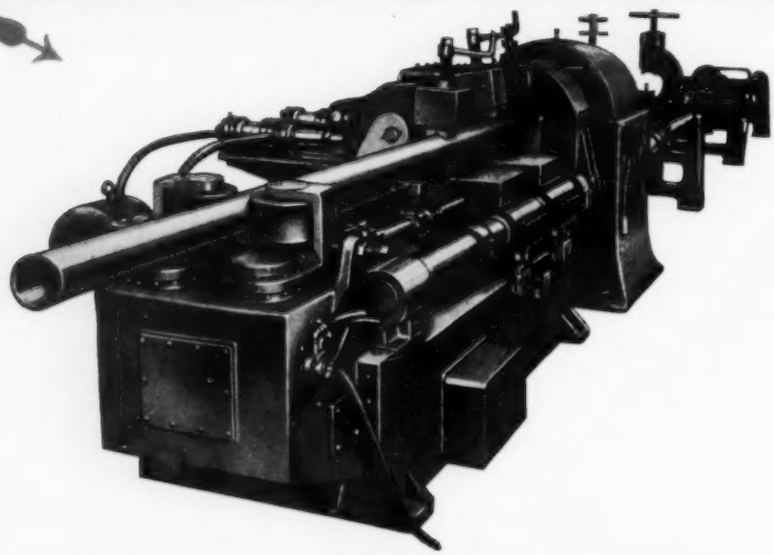
...100% chip recovery

CONTINUOUS • AUTOMATIC • CENTERLESS

BAR & TUBE TURNERS

For speed... and for precision! Continuous, automatic feeding gives you high production unequalled by any other type of turning machine! For both rough peeling and finished precision conditioning, Medart Centerless Bar Turners will turn bars and tubes at maximum rate obtainable from any present day cutting tools. The machines are very flexible. May be used with one or two cutterheads, with one or up to eighteen tools in each head.

"Patents make Jobs"



MANUFACTURING ENGINEERS OF COMPLETE TRANSMISSION EQUIPMENT AND SPECIALIZED MACHINERY

MEDART

THE MEDART COMPANY • 3500 DE KALB ST., ST. LOUIS, MO.

pay, employes will be paid for any current year's vacation time which they might still have coming but have been unable to take, Mr. Turner explained.

GE FORMS MOBILIZATION PLANNING COMMITTEE

▲ The formation of a Mobilization Planning Committee within the General Electric Co.'s apparatus department has been announced. The new group's responsibilities are to co-ordinate for the department the "requests from the Department of Defense and its agencies for information concerning facilities, personnel, possible production schedules and other matters of material procurement planning for nation defense."

KOPPERS BUILDS COKE PLANTS IN ALABAMA

▲ Alabama By-Products Corp., which operates a large foundry coke and coal-chemical plant at Tarrant, Ala., near Birmingham, has awarded Koppers Co., Inc., a contract to construct a battery of 29 new chemical-recovery coke ovens. Engineering work will begin at once, and the new battery is expected to be completed within a year.

The new coke oven battery will consist of 29 Koppers, Becker-type ovens, underfired with coke oven gas. At 20 hours coking time, they will produce 150,000 tons of coke annually. Alabama By-Products Corp. now has a total of 174 ovens, and the new battery will bring the total to 203.

Koppers also will furnish new coke oven machinery and will build an ammonia absorber for the Birmingham company.

FRICK OPENS NEW AND OLD COAL MINES

▲ H. C. Frick Coke Co. announced that a new 4000-ton a day coal mine will be opened in Washington County and another mine of the same capacity, closed since 1928, will be reopened in Fayette County, to help meet the continuing demand for additional coal required to make more steel for national defense purposes.

The new mine will be developed between Vestaburg and Fredericktown. Construction plans include a

river tipple for loading barges to carry the coal down the Monongahela River 42 miles to the Carnegie-Illinois Steel Corp.'s by-product coke plant at Clairton, Pa.

The closed Collier Mine in the Fairchance district, near Uniontown, Pa., will be rehabilitated to assure a continued supply of coal for nearby beehive coke ovens. Mining was discontinued there 22 years ago in favor of mines having facilities for river shipment of coal to by-product coke plants. All coal mined there after the reopening will be coked in the adjacent beehive ovens.

Collier Mine is expected to be ready for mining operations in about one year. The Washington County mine is scheduled to start producing early in 1952.

A new road is now being constructed leading to the new mine in the Centerville Borough district, across the Monongahela from Frick's Maxwell Mine. This will be the first mine in that immediate area, identified as Brown's Fifth Pool Field.

Pumping of water from Collier Mine has been started in the first step toward its reopening. Collier will undergo a complete realteration of both surface and underground facilities.

PENNSYLVANIA SALT COMPLETES FIRST CENTURY

▲ When the Pennsylvania Salt Manufacturing Co. was organized in September, 1850, there were only 51 persons employed in America's infant steel industry. Cast and wrought iron, brass, copper and bronze, laboriously machined, finished and polished by hand, were the metals of our young industry. What chemicals were used in metal working were few and basic and the great scientific advances which were to weld chemistry and metallurgy together to make possible the modern world were still unknown.

Today the steel and aluminum industries are two of Pennsalt's largest customers and virtually every other phase of America's vast metal working industry is served by some product of this century-old chemical manufacturer.

Pennsalt was organized by five young Philadelphia Quakers to manufacture "the alkaline salts of soda." Since most of the eastern seaboard industries were importing what chemicals they used from Europe, the company founders chose the expanding Midwest for their market and built their first plant at its gateway—at Natrona on the Allegheny river near Pittsburgh.

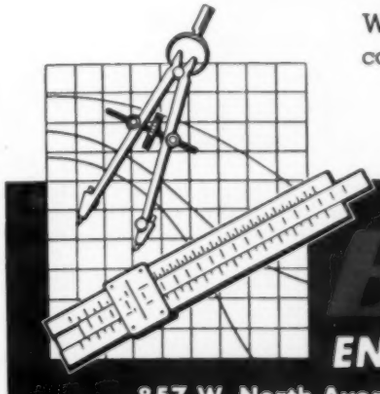
As the steel industry grew in the Pittsburgh area, Pennsalt began to supply it with chemicals—at first acids for pickling and later others. In 1864 Pennsalt began importing cryolite from Greenland as a source for soda alkalies and alum. A by-product was calcium fluoride, which the company sold to early steel makers as a flux.

Beginning in the 1870's and until after World War I, Pennsalt was a small but active producer of metals themselves. As a source of sulfur, the company imported pyrites from Spain. This ore also yielded small but profitable amounts of copper, gold, silver and iron oxide. The non-ferrous metals were refined in Pennsalt's Natrona plant and a newer one at Greenwich Point in Philadelphia. The iron oxide, called "blue billy," was sold in fairly large quantities to steel mills.

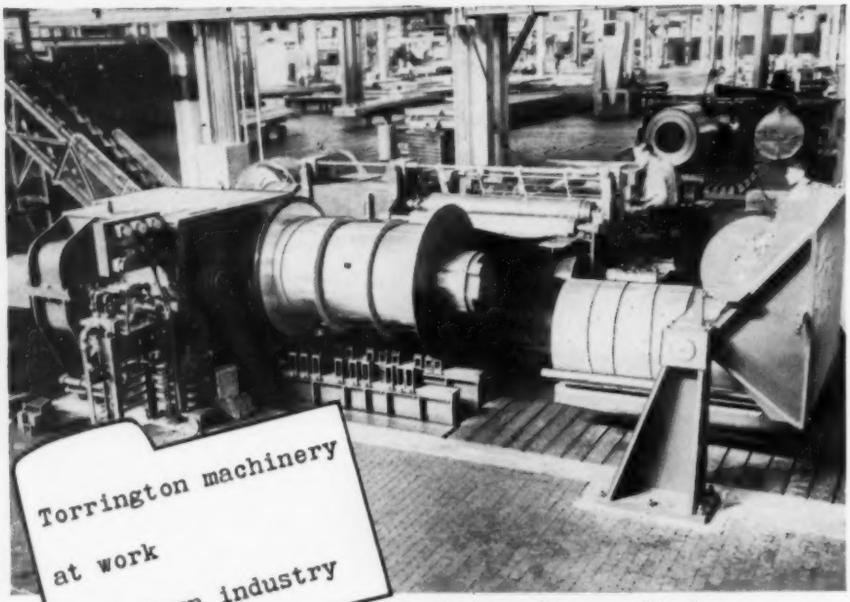
It was in connection with this work that the Wedge furnace for ore roasting, predecessor to the modern Herreshoff furnace, was developed (1904)

Designed for specialized applications, the new Bloom HTR Burner will release up to 750,000 Btu per cubic foot of combustion volume. Exceptional results have been shown where quick heating and intense concentration of heat are required.

Write for Bulletin 1081 giving complete details.

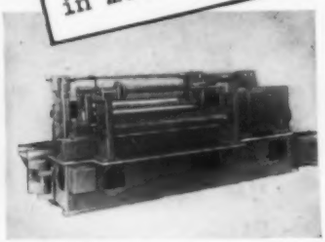


BLOOM
ENGINEERING CO., INC.
857 W. North Avenue Pittsburgh 33, Pa.

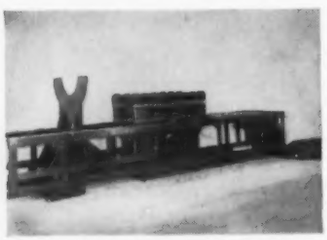


Torrington machinery at work in modern industry

Torrington slitter at work in plant.



Torrington's Latest Slitting Equipment in Newest Plant of ALUMINUM COMPANY OF AMERICA



The newly constructed plant of Aluminum Company of America, Davenport, Iowa, houses the last word in slitting equipment by Torrington. This heavy duty machinery combines famous Torrington standards—advanced design—dependable accuracy plus ability to withstand abuse under exacting heavy service. This unit contains feed rolls, slitter, scrap chopper, winder, collapsible block, stripper, elevator carriage upender and scrap conveyor. Outstanding features are:

- Speed as high as 1200 feet per minute
- Rugged, heavy construction for mill production service
- Anti-friction bearings
- Air-operated clutches to allow either pull-through or positive drive operation of slitter
- Swing shelf for inter slitter housing for ease of changing cutter set-ups
- Scrap chopper driven from independent motor
- Power expansion of collapsible block
- Stripping and upending by power

Top: Slitter part with feed rolls. Next: Stripper and elevator carriage. Last: Winder.

Call or write Torrington today for information and name of nearest Torrington representative

The TORRINGTON

MANUFACTURING COMPANY TORRINGTON, CONNECTICUT

DESIGNERS AND BUILDERS OF MILL MACHINERY FOR OVER 60 YEARS

and for a time marketed by Pennsalt.

During this period Pennsalt played an important part in one of America's most exciting industrial developments. Charles Martin Hall, in 1886, discovered that Pennsalt's cryolite was, in its molten state, the electrolyte for reduction of aluminum. The new use for the Greenland ore quickly overshadowed all others and today it plays an essential part in our aluminum production.

In addition to supplying this to the Pittsburgh Reduction Co. (later Alcoa), Pennsalt was in position to furnish them their basic ingredient, alumina, from its recently acquired Bayer process, the first in America.

The few uses for chlorine in the early 1900's definitely limited the caustic soda production. Therefore, outlets for this comparatively new gas were eagerly sought. Once again metallurgy played an important role. Pennsalt's first large chlorine customer was the Goldschmidt Detinning Co. (later the Metal & Thermit Corp.), who used quantities to recover tin from scrap.

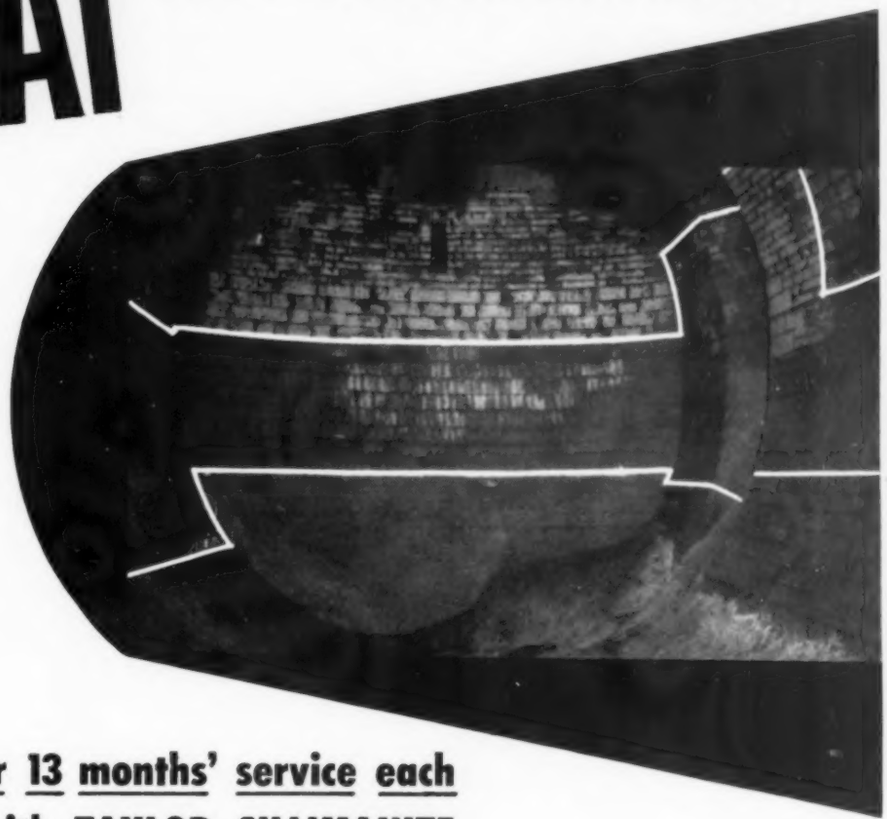
Today Pennsalt's special chemicals department handles more than 50 chemical specialties for the metal industry, including acid, alkaline and emulsion type cleaners; rust inhibitors; pickling and descaling compounds; maintenance cleaners, and corrosion resistant cements and paints. Research is adding more, not only in the field of cleaners but other chemicals for the metal industries.

Among the users of these products are approximately 90 per cent of America's tinplate producers.

SIER-BATH APPOINTS COUPLING REPRESENTATIVES

▲ Sier-Bath Gear and Pump Co., North Bergen, N. J., recently appointed the following companies representatives for the Sier-Bath gear couplings: J. R. Ruddock & Associates, 7001 N. Clark St., Chicago 26, Ill. Territory: Northeastern Illinois, including the Chicago metropolitan area (bordering counties in Michigan). Volco Co., 622 McKnight Bldg., Minneapolis 1, Minn. Territory: States of Minnesota, Iowa, South Dakota, North Dakota, Northwestern Illinois and Peninsula of Michigan. W. B. Conrad Co., 506 Curtiss Building, Detroit 2, Mich. Territory: Southeastern Michigan.

COMBAT JOINT EROSION IN HOT METAL MIXERS



Taylor Sillimanite (TASIL) Brick, laid with TASIL No. 301 Cement in the zones of excessive wear (a 13½" thick band around the front, back, end walls and floor of the pour-out spout, and 18" x 18" x 6" blocks for jambs of pour-out spout) is tripling the life of hot metal mixer linings.

Field reports show over 13 months' service each for two mixers lined with TAYLOR SILLIMANITE

Field report on 1000-ton mixer

This company has just completed the third campaign in which more than a million tons each have been tapped on Taylor Sillimanite balanced mixer linings. The last campaign totaled 14 months with not a single brick replaced for the first 12 months. The material and labor costs for the campaign were 20% lower than the best campaign on high-heat duty firebrick linings.

Field report on 500-ton mixer

Previous lining material lasted approx. four months, with less than one-half million tons produced. A Taylor Sillimanite lining has now been in service for 13 months, 9 days, without even a minor repair, handling around 2400 tons of iron per day.

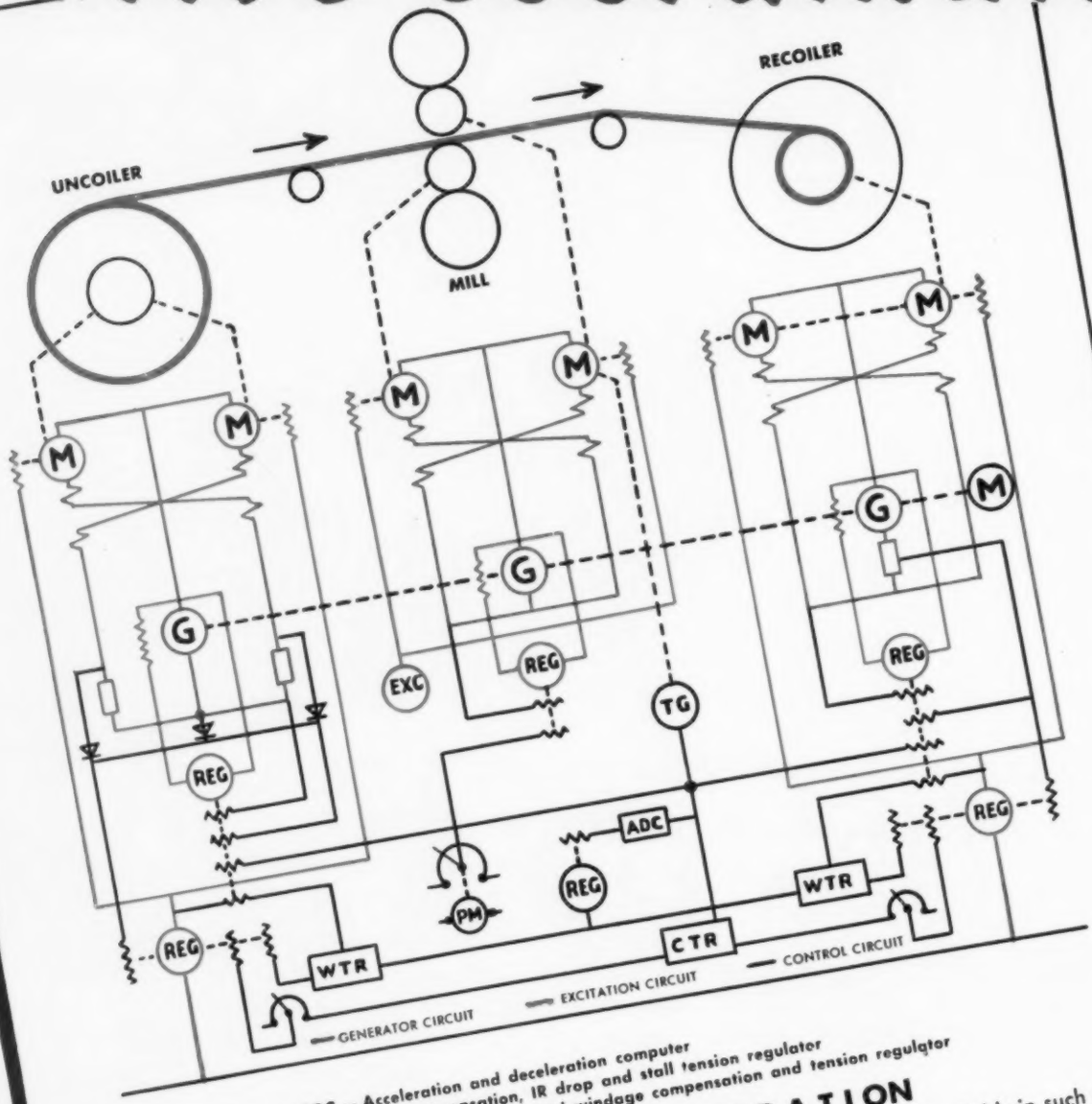
- Despite higher first cost, Taylor Sillimanite Brick linings have paid for themselves through savings in material and masonry costs alone. The real saving however, is in the elimination of frequent mixer downtime. It will pay you in profits to discuss this TASIL application with your Taylor Field Representative.

Refractorers to industry since 1864.

Exclusive Agents in Canada:
REFRACTORIES ENGINEERING AND SUPPLIES, LTD.
Hamilton and Montreal

The CHAS. TAYLOR SONS Co.
REG. U. S. PAT. OFF.
MANUFACTURERS OF REFRACTORIES • CINCINNATI • OHIO • U. S. A.

Drive coordination



ADC — Acceleration and deceleration computer
WTR — WR^2 compensation, IR drop and stall tension regulator
CTR — strip speed, friction and windage compensation and tension regulator

SUMMARY OF OPERATION

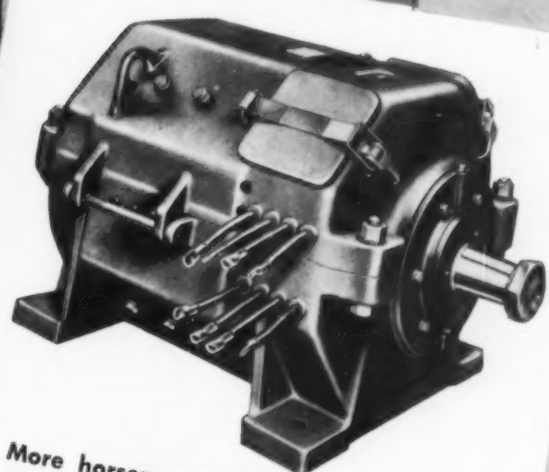
All operations are performed from an operator's cabinet at each end of the mill. Threading the strip through the single stand mill is accomplished in minimum time. Strip tension between mill and reels is then regulated to any desired value by means of the current regulating exciters of each reel. By proper adjustment of the IR drop, friction-windage and strip speed compensation features, the tension may be held constant as required to provide a uniform quality of the processed strip. Any change in reel motor current and thus the tension, is translated to the regulators which immediately modify the reel motor fields in such a way as to re-establish the tension. Sudden transient requirements of a wider current modification are also translated to the voltage regulators of the reel generators which immediately respond to assist in establishing the desired current. The required change in current and torque when accelerating and decelerating a coil is measured by a WR^2 compensating device which responds to actual rate of change in speed of the mill tachometer generator (TG) and thus insures the proper compensation with any rate of acceleration.

Elliott COMPANY
Dept. 15, Ridgway Division, RIDGWAY, PA.
Plants at: JEANNETTE, PA. • RIDGWAY, PA.
AMPERE, N.J. • SPRINGFIELD, O. • NEWARK, N.J.
DISTRICT OFFICES IN PRINCIPAL CITIES

by ELLIOTT...

Modernization of No. 3 Temper Pass Mill at Irvin Works of Carnegie-Illinois Steel Corporation. Using Elliott motors and generators, the entire drive was coordinated by Elliott, with Cutler-Hammer control.

ooking down on the E. W. Bliss mill. center foreground, the two 600-hp, 50/1000-rpm enclosed force-ventilated main roll twin-drive motors. At ft, the two tandem-coupled 500-hp, 50/965-rpm recoiler motors. The odernization increased mill speed om 500 to 2500 fpm, with provision r future increase to 3750 fpm, by ar changers.



And—

another steel industry achievement—the new CROCKER-WHEELER 600 SERIES MILL MOTOR...

More horsepower without added bulk. Maximum accessibility, too, with the hinged, split frame. Pace-setting internal construction. Steel men wrote the ticket on this new, tough auxiliary mill motor. Here it is — Ask for the bulletin.

MR-6

STEAM TURBINES • GAS TURBINES • GENERATORS
MOTORS • CONDENSERS • FEEDWATER HEATERS
AND DEAERATORS • STEAM JET EJECTORS
CENTRIFUGAL BLOWERS • TURBOCHARGERS FOR DIESEL ENGINES
TUBE CLEANERS • STRAINERS • EXPANDERS • FILTERS

Here's How to Erase Smoke Troubles

VIOLATION OF SMOKE ORDINANCE

LOSS OF FUEL ECONOMY

BAD COMMUNITY RELATIONS

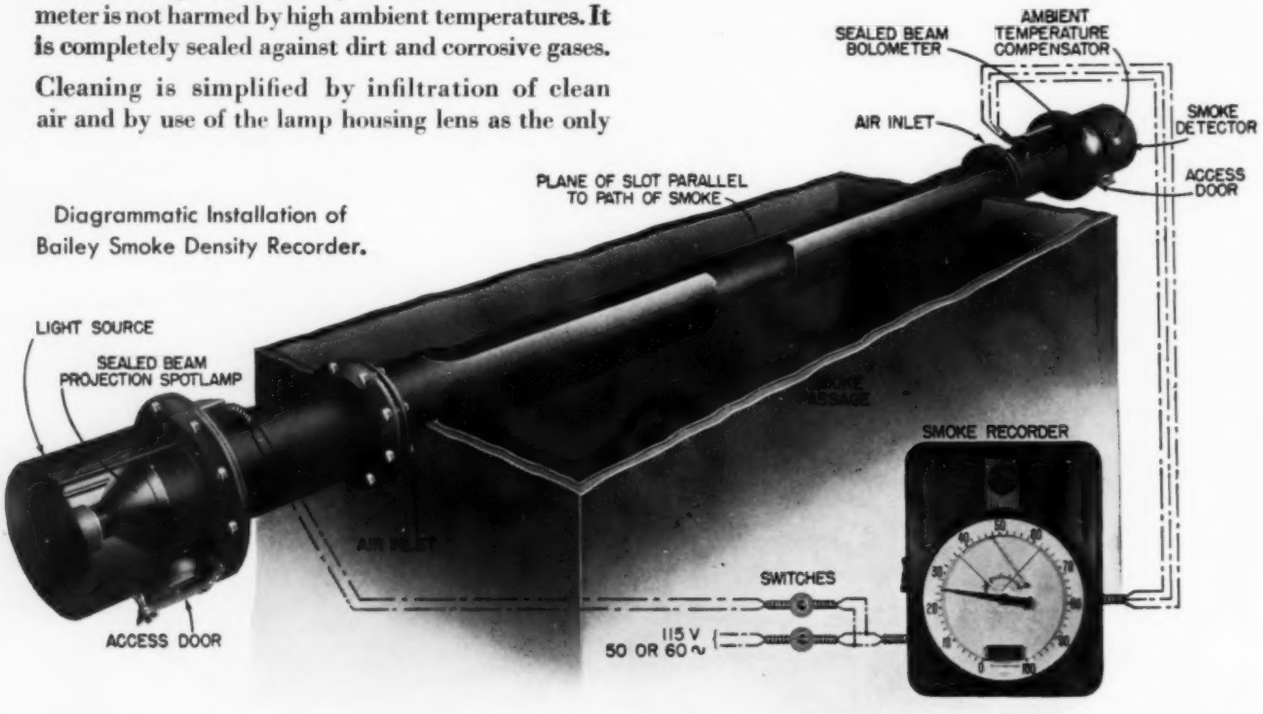
★ One of your first steps in erasing these troubles which result from excessive smoke, should be the installation of a Bailey Smoke Density Recorder. This 24-hour recorder is not an ordinary photo-cell instrument. Instead it detects smoke density by a Bolometer which is simply a sturdy tungsten filament and a parabolic mirror, mounted in a standard sealed beam automobile head lamp housing.

In using this simple, unique smoke detector, you do not have to provide cooling devices since the Bolometer is not harmed by high ambient temperatures. It is completely sealed against dirt and corrosive gases.

Cleaning is simplified by infiltration of clean air and by use of the lamp housing lens as the only window between the Bolometer and the gas passage.

It's easy to secure and maintain alignment of the sealed beam light source with the Bolometer since they are mounted at opposite ends of a slotted pipe which extends across the smoke passage.

For complete information on how you can profitably use this unique instrument to erase your smoke troubles, ask for Bulletin 211, "Bailey Smoke Density Recorder".



Diagrammatic Installation of Bailey Smoke Density Recorder.

G-29

BAILEY METER COMPANY

1047 IVANHOE ROAD, CLEVELAND 10, OHIO • BRANCH OFFICES IN PRINCIPAL CITIES

BAILEY METER COMPANY LIMITED, MONTREAL, CANADA

Let Bailey Smoke Density Recorders Watch Your Stacks

IT'S HERE!

...THE "CARRIER" STEEL MEN ASK FOR!

ROSS Series 100

NOW STEEL MILLS CAN TAKE ADVANTAGE OF STRADDLE CARRIER MATERIALS-HANDLING . . . SMASH BOTTLE NECKS INHERENT IN ORDINARY METHODS!

Ross Series 100 . . . The *Only* Stradle Carrier Designed and Built for Rough, Tough Steel Mill Service!

It's Rugged, It's Tough . . . Has That Great Reserve Strength Steel men Want!

It's Self-Loading, Unloading . . . Only a Driver Needed!

45,000 Lb. Payloads, 33 MPH Forward or Reverse!

Don't overlook the outstanding advantages of the *simplest mass handling method known!* Get full details on Ross Series 100 Carrier. A 'phone call, wire or letter will do it!

Rely On ROSS

THE ROSS CARRIER COMPANY
400 Miller Street
BENTON HARBOR, MICHIGAN, U. S. A.

LOOK AT THESE ADVANTAGES OF CARRIER HANDLING!

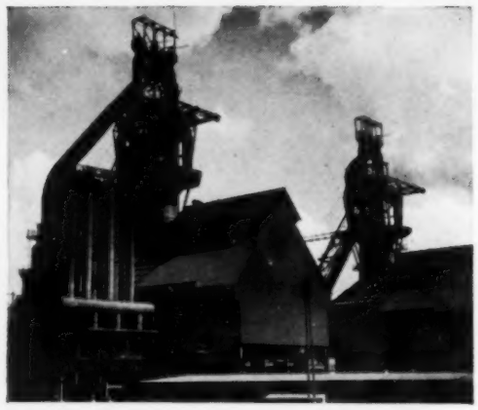
Simplest known method for moving billets, bars, in process and finished materials . . . *where* needed *when* needed, at a moment's notice.

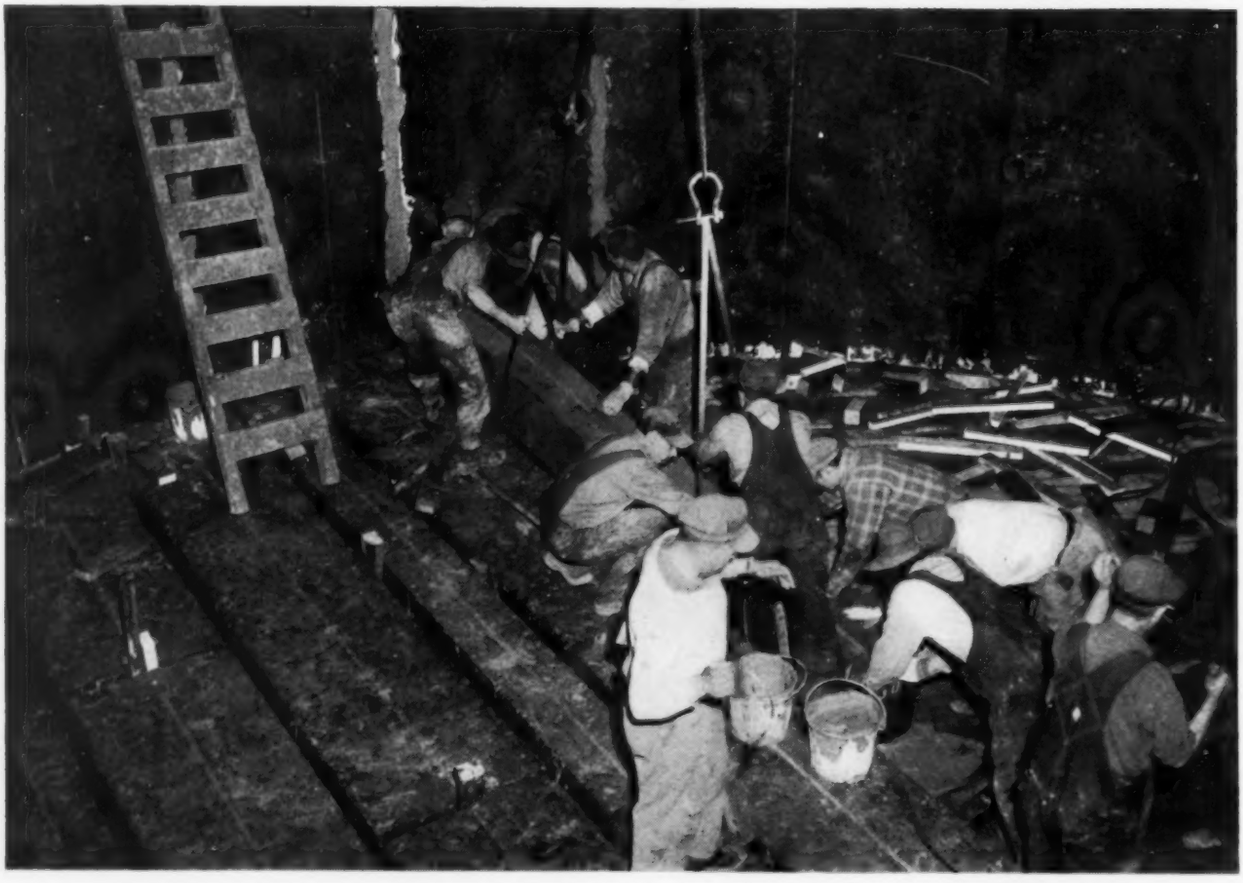
Frees steel mills from restrictions of plant railroad handling systems. Eliminates need for expensive trackage, cars, locomotives . . . costly, time-consuming switching operations.

Prevents congestion in the mill . . . eliminates costly re-handling . . . saves time and money in getting out current orders . . . frees more mill space for production operations.

1,841,000 TONS WITH ONE "NATIONAL" CARBON LINING!

. . . and still going strong!





● Carbon is the ideal material for lining blast furnaces. One example proving this statement is the record of one of the largest blast furnaces in this country, in which a "National" carbon block lining was installed several years ago. This furnace has produced approximately 1,841,000 tons of iron as of September 1, 1950 and is still going strong with the original lining.

The terms "National" and "Eveready" are registered trade-marks of

NATIONAL CARBON DIVISION
UNION CARBIDE AND CARBON CORPORATION
30 East 42nd Street, New York 17, N. Y.
District Sales Offices: Atlanta, Chicago, Dallas, Kansas City, New York, Pittsburgh, San Francisco
Foreign Department: U. S. A.

MORE THAN DOUBLE THE USABLE LIGHT!

The biggest news since the invention of flashlights—the brand new, leak-proof "Eveready" No. 1050 flashlight battery—gives more than double the usable brilliant white light for critical uses than any other flashlight battery we have ever made.

●

NO METAL CAN TO LEAK OR CORRODE

Personnel News...

W. A. Steele has been named general manager of Wheeling Steel Corp.'s Steubenville, Ohio, plant. Mr. Steele was formerly general manager of the Benwood, W. Va., plant. **A. H. Shonkwiler** and **T. R. Moxley** have been named assistant general managers of the Steubenville works of Wheeling Steel Corp. Mr. Shonkwiler was formerly general manager of the Lackawanna works of Bethlehem Steel Co., Lackawanna, N. Y. Mr. Moxley was formerly general master mechanic at the Steubenville plant of Wheeling Steel Corp.

E. E. (Bud) Bauer was named as a contract engineer for the Heyl and Patterson Co., Pittsburgh, Pa. He will serve the steel and utility market in the western territory. Mr. Bauer graduated, with a B.S. degree, from the University of Wisconsin and obtained his M.S. degree from the University of Pittsburgh. After passing the test course of General Electric he served seven years in that company's Pittsburgh division. Later he was sales manager for the centrifugal pump division of Peerless Pump Division of Food Machinery Corp., Quincy, Ill., and then promoted to central district manager for Peerless in Chicago, Ill.

H. G. Dillon was named vice president in charge of sales and **B. A. Rose** as vice president in charge of engineering for Heyl & Patterson Co., Pittsburgh, Pa. For the past four years Mr. Dillon has been sales manager and Mr. Rose has been director of engineering. **E. W. Kahle** has been advanced from assistant treasurer to treasurer.

W. D. Millar and **H. E. Kaufman** were appointed division superintendent and assistant division superintendent of blast furnaces, respectively, at the South Chicago plant of Carnegie-Illinois Steel Corp. Mr. Millar succeeds **J. M. Stapleton** who recently was promoted to assistant to vice president. Mr. Millar started at South works as a blast furnace apprentice in 1936 shortly after graduation from the University of Alabama with a degree in chemical engineering. Since that time, he was employed at South works in various capacities including that of blower, general foreman and departmental superintendent. In 1949 he became assistant division superintendent of blast furnaces, the position he held at the time of his new appointment. Mr. Kaufman who succeeds Mr. Millar, goes to South works from the corporation's Duquesne (Pennsylvania) plant where he has been assistant superintendent of blast furnaces since 1946. His first association with Carnegie-Illinois was at South works as a blast furnace apprentice in 1936. He was transferred to Pittsburgh as an industrial engineer in 1941, and subsequently served in the raw materials, fuel and power division and as assistant to superintendent of blast furnaces at Duquesne. He is a graduate of the University of Wisconsin.

William G. McClain was named sales engineer for E. W. Bliss Co. Mr. McClain has had considerable experience in the steel industry, being formerly associated with Republic, Inland, Wheeling and Bethlehem. He was superintendent of Bethlehem Steel Co. at the Sparrows Point, Md., cold reduction mills for twelve years. After the war, he was commissioned by the War Department to visit Japan and prepare a comprehensive report on the steel industry in that country. His most recent connection was with Furnace Engineers, Inc., of Pittsburgh, as sales engineer. Mr. McClain will operate from the Bliss rolling mill division's headquarters in Salem, Ohio.

John L. Fuller has been appointed to the post of technical coordinator for Reliance Electric and Engineering Co., with responsibility for engineering coordination of special drives, technical investigations, analysis of special projects, and direction of Reliance's experimental program. A veteran of the motor industry, Mr. Fuller has been with Reliance for 14 years, where in his previous position he was responsible for engineering on the company's large motors. **Charles R. Sutherland,** who formerly directed engineering for smaller size Reliance motors, has been promoted to the new position of manager of engineering for the company's Ivanhoe division products. His new responsibilities include direction of the large motor engineering group and the high fre-

T. R. MOXLEY

B. A. ROSE

E. E. BAUER

H. G. DILLON

LINTERN
AIRE-RECTIFIERS
Proven By Performance
Used By Leaders

Here is a partial list of users of Lintern Aire-Rectifiers. Several companies have up to twenty Aire-Rectifiers in a single plant.
We value highly the confidence thus expressed in our product.

Allegheny-Ludlum Steel Corporation
Aluminum Company of America
Tennessee, Texas, and Davenport, Iowa, Plants
American Steel & Wire Company
Andrews Steel Corporation
Atlantic Steel Company
Atlas Steels, Limited
Bethlehem Steel Corporation
Bethlehem, Lackawanna, Steelton, and Sparrows Point
Birmingham Slag Company
Canadian Carborundum Company
Carnegie-Illinois Steel Corporation
Gary, South, and MacDonald Works
Colorado Fuel and Iron Company
Columbia Steel Corporation
Electro-Metallurgical Company
Ford Motor Company
Detroit and Candian Plants
Geneva Steel Corporation
Great Lakes Steel Corporation
Inland Steel Company
Jones and Laughlin Steel Corporation
Kennecott Copper Company
Keystone Steel and Wire Company
Laclede Steel Company
McClouth Steel Corporation
National Tube Company
Lorain and McKeesport Works
Northwestern Steel and Wire Company
Pittsburgh Metallurgical Company
Reynolds Alloy Corporation
Republic Steel Corporation
Cleveland
Rotary Steel Company
Southern Acid and Sulphur Company
Stanley Works, American Tube and Stamping Plant
Timken Roller Bearing Company
U. S. Navy
Weirton Steel Company
Westinghouse Electric Company
West Virginia Pulp & Paper Company
Wheeling Steel Company
Wisconsin Steel Company
Youngstown Sheet and Tube Company
Indiana Harbor

Lintern Aire-Rectifiers have been installed also on cranes for England, France, South Africa, and Chile.

SUCH *Preference* MUST BE MERITED

ASK FOR NEW BULLETIN 4912

THE LINTERN CORPORATION
54 LINCOLN AVENUE - BEREA, OHIO

quency engineering group. Mr. Sutherland has served in various engineering capacities at Reliance for the past 11 years. The third new Reliance engineering post, that of manager of engineering for the Ashtabula division products, will be filled by **Earl C. Barnes.** Mr. Barnes joined Reliance in 1940, and since 1947 has been responsible for electrical design of both a-c and d-c products manufactured at the Ashtabula, Ohio, plant.

Harry L. Jenter, works superintendent of Cuyahoga works, the company's largest plant in the Cleveland area, was named to succeed **Robert E. Cramer** as chief engineer of American Steel and Wire Co. Mr. Cramer, chief engineer since 1945, was appointed to the newly-created post of chief engineer for the Cyclone Fence division.

Harry S. Griffith retired August 31 after 52 years of continuous service with Manning, Maxwell & Moore's Shaw Box Crane and Hoist division, Muskegon, Mich. Mr. Griffith started with the company at Muskegon in 1898 and successively has been an erector, erection superintendent, service engineer, and sales engineer. All through his career he has maintained headquarters

HARRY S. GRIFFITH

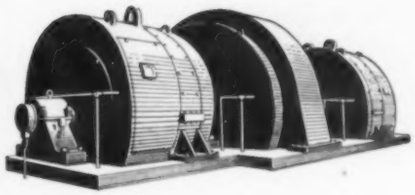
at Pittsburgh, Pa. For the past 30 years he has been engaged in sales work and as a consultant on difficult or unusual service and erection jobs. Mr. Griffith's successor is **C. W. Ashcom** who has been connected with the Pittsburgh office for several years. Prior to that time he was associated with the Carnegie-Illinois Steel Corp. for thirteen years.

Atwood Austin, formerly financial consultant for several of the Kaiser companies, was appointed vice president and treasurer of Kaiser Steel Corp., Oakland, Calif. **C. F. Borden,** general sales manager of Kaiser Steel since 1947, was named vice president in charge of sales.

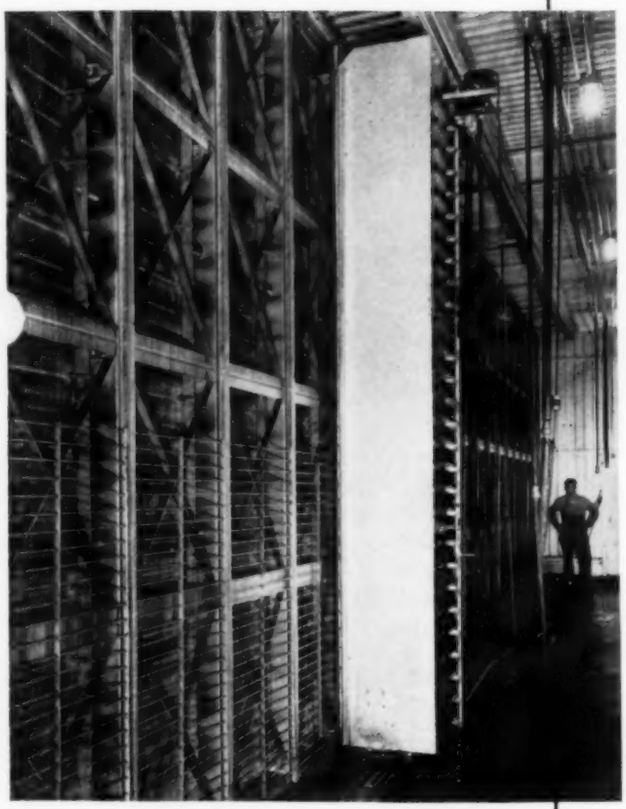
Frank E. Nutt, manager of electrical sales, Chicago district, Elliott Co., and formerly Chicago district manager for Crocker-Wheeler, has been appointed district manager of the new Denver, Colo., office of the Elliott Co. Prior to Mr. Nutt's association with the Crocker-Wheeler Electric Manufacturing Co., in 1942, he was, for eight years employed by the General Electric Co. Mr. Nutt is a native of Denver and a graduate of the University of Denver.

Jan R. Dunsford of Pittsburgh, Pa., announces the opening of a Cleveland, Ohio, office with **W. Don**

Where SUPER-CLEAN AIR for mill motors is a "must"



AAF Electro-Cell combines high cleaning efficiency with ease of maintenance



An Electro-Cell Precipitator of 216,000 CFM capacity with AAF automatic washers now in its third year of service.

WHERE conditions permit no compromise in the cleanliness of the air supplied for cooling mill motors, the AAF Electro-Cell is your logical choice. This electronic precipitator gives positive protection against dust and smoke—even down to fractional micron sizes.

Removable collector plate cells permit selection of maintenance method best suited to your operation. Cells may be manually washed and re-oiled in place; removed for easy cleaning in a special tank, or washed, dried and recoated automatically (as illustrated) with minimum interruption to operation.

Electro-Cell's sectional construction reduces weight of parts, eliminates multiplicity of electrical connections, protects wiring from dirt and water. And its full-height hinged or removable ionizers minimize electrical losses, reduce ozone and simplify replacement of ionizing wires.

If you want super-clean air plus proven savings in operation and maintenance, get complete Electro-Cell data now. Just contact your local AAF representative or write direct for Bulletin No. 252.

AMERICAN AIR FILTER COMPANY, INC.
302 Central Avenue, Louisville 8, Ky.
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®AAF

AIR FILTERS
AND DUST CONTROL EQUIPMENT

CRANE BUILDERS Since 1903

BEDFORD CRANES

Capacities 5 to 150 Tons

Any Span or Lift
Send For Your
Copy Of Catalog

Designed and
Engineered to Meet
Your Requirements

ELECTRIC OVERHEAD TRAVELING CRANES
GANTRY CRANES • STEEL DERRICKS
BUILT TO YOUR SPECIFICATIONS
STRUCTURAL STEEL • STEEL BUILDINGS

BEDFORD FOUNDRY & MACHINE CO.

Engineers
Designers
Fabricators

BEDFORD, INDIANA
U. S. A.

Gray
Iron
Castings

Logan, formerly of Westinghouse Electric Corp. with offices in the Caxton Building. They are representing Electro Dynamic works of the Electric Boat Co., Pelham Electric Manufacturing Corp., and Green Electric Sales Corp.

M. C. Larson was named manager of the Baltimore, Md., sales office of Cutler-Hammer, Inc., replacing **R. A. Haworth** who has been appointed Dallas district sales manager for Cutler-Hammer.

M. C. LARSON

Bascom H. Caldwell, Jr. has been named assistant manager of engineering in the large motor and generator engineering division, General Electric Co., Schenectady, N. Y. **D. E. Brainard, Howard D. Snively, Robert V. Shepherd,** and **Robert W. Wieseman** were named division engineers.

Harry W. Dole, Jr., formerly electrical engineer for Continental Foundry and Machine Co., has taken a position as staff engineer with Columbia Steel Co., Pittsburg, Calif. Mr. Dole was formerly with Westinghouse Electric Corp., National Tube Co., and United Engineering and Foundry Co.

W. J. Binder was named manager of the engineering service department of A. M. Byers Co., Pittsburgh,

W. J. BINDER

Pa. Mr. Binder, an engineering graduate of the University of Pittsburgh, has been with the Byers organization since 1946.

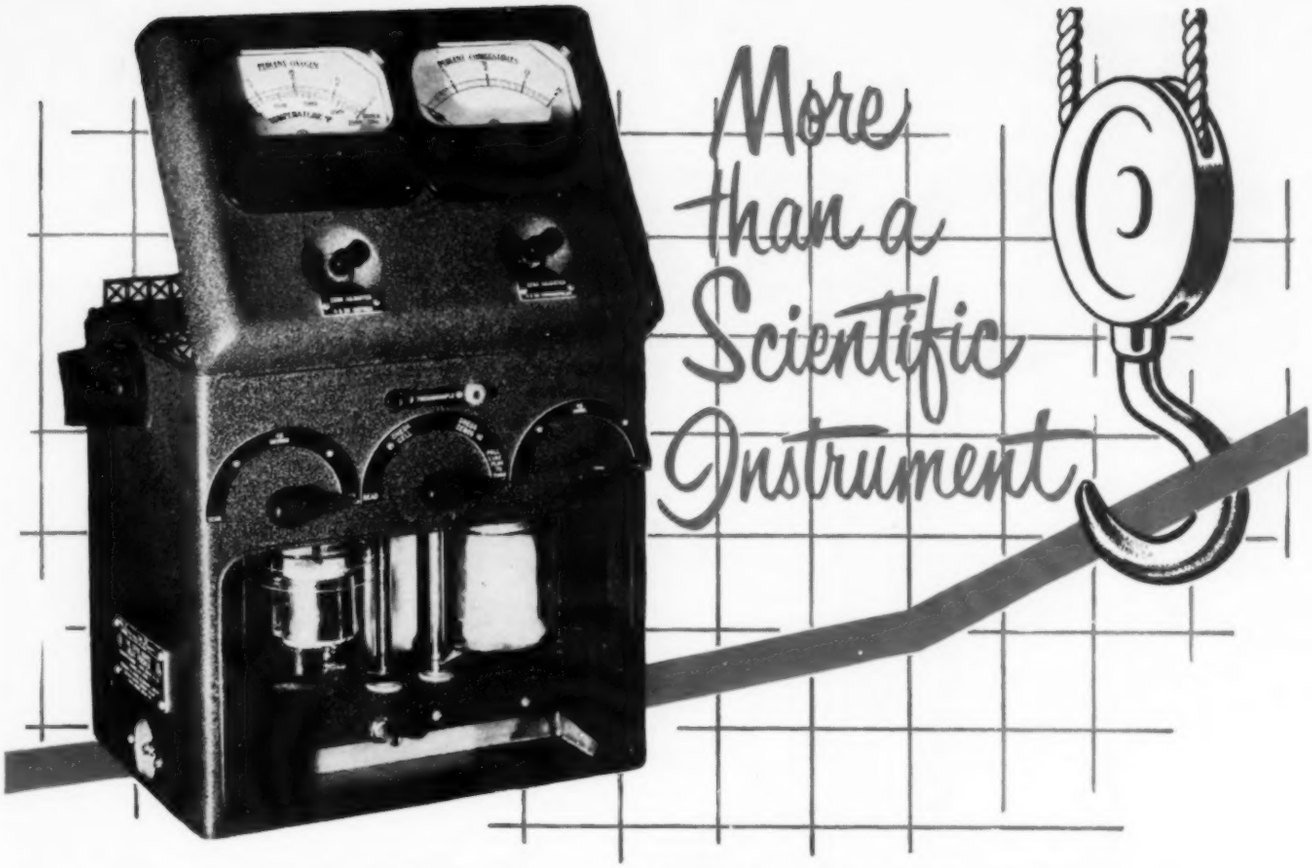
Victor Fedosky has been appointed assistant manager of the Ambridge, Pa., plant of American Bridge Co. He has been assistant to plant manager at the company's Gary, Ind., plant.

E. V. Crane has returned to the E. W. Bliss Co.'s engineering staff. Mr. Crane was formerly with Bliss for 25 years. He left during the war to accept a position with Sam Tour & Co., research and engineering organization, as vice president in charge of mechanical engineering. Later he was chief engineer of the Hydraulic Press Manufacturing Co. Mr. Crane will make his headquarters shortly at the new Bliss plant at Canton,

E. V. CRANE

Ohio, where the building of rolling mills and large mechanical and hydraulic presses will be centered.

Nelson W. Dempsey, general superintendent of American Steel and Wire Co. at the Waukegan, Ill., plant, has been named to a similar post at the Cuya-



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A right angle unit built for heavy duty performance in any industry. The worm can be above or below the gear. Shafts single or double extended for coupling connections or chain or gear drives.
They are built in ratios from 4 to 1 to 90 to 1 and in capacities from ¼ to 100 H.P.
Bulletin No. 68 covers selection tables and dimensions.

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PULLEYS • GEARS • V-BELT SHEAVES • ANTI-FRICTION
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hoga works in Cleveland, Ohio, which along with its wire-drawing facilities includes the nation's largest cold roll strip mill. He fills the vacancy created by the recent appointment of **Harry L. Jenter** to the position of chief engineer of the company. **James E. Brown,** present assistant general superintendent at Cuyahoga works, was named to the general superintendency at Waukegan.

W. C. Harris has been appointed manager of engineering of the locomotive and car equipment divisions of General Electric's apparatus department. He succeeds **H. W. Gouldthorpe,** recently appointed manager of the transportation divisions in Schenectady, N. Y. **R. A. Hutchins** was named to the newly created post of assistant to the manager of the locomotive and car equipment divisions.

W. C. HARRIS

William B. Snyder has been appointed assistant manager of the steel mill division at the General Electric Co.'s apparatus department. In the newly created post, Snyder will assist in the supervision of the application of electrical apparatus in steel mills.

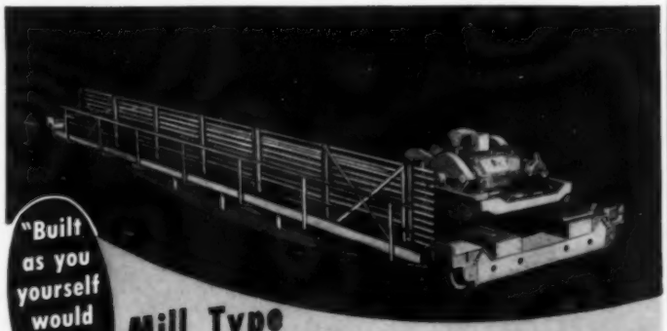
K. L. Konnerth, formerly general manager of operations, was elected vice president and general manager of operations of the H. C. Frick Coke Co. and the United States Coal and Coke Co. In this position Mr. Konnerth will direct the operating policies of these companies.

Obituaries

F. H. Janecek, Sr., 52, chief blast furnace engineer, Republic Steel Corp., Cleveland, Ohio, died September 23.

Lee B. Patin, 46, died August 23. Mr. Patin had been assistant chief engineer at Carnegie-Illinois Steel Corp. since 1948. A native of Uhrichsville, Ohio, he was widely known here for his work in smoke prevention. Mr. Patin joined Carnegie-Illinois in 1940 as a construction engineer for the firm's defense engineering staff in Charleston, W. Va., and was transferred to Pittsburgh in 1943.

W. E. Reiber died in Cleveland, Ohio, September 27. Mr. Reiber, who was assistant chief electrician, Great Lakes Steel Corp., Ecorse, Mich., was to be chairman of the Detroit district section of the AISE for the coming season. Mr. Reiber was born in Butler, Pa., where he received his elementary schooling. He was grad-



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Satisfying A.I.S.E. specifications, Browning Mill Type Cranes incorporate types of motors and controls on which you have standardized. This flexibility suits your VRB crane *perfectly* to your needs. Our design, springing from 49 years' experience, places plenty of strength where it is required.

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Husky 10-ton mill type trolley equipped with separate load girt for easy removal.

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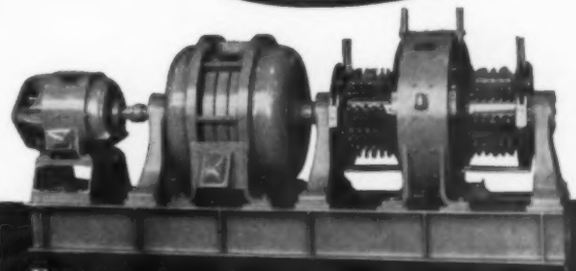

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25 Years of Progress

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enables you to Save Valuable Space... Keep Materials Moving ... Simplify Maintenance

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One of the first installations of Reliance Motors specifically designed for runout table use was made in this steel mill.

One of the highlights of Reliance's specialization in designing and engineering motor-drives for steel mills has been its quarter of a century of leadership in motors for runout tables. Today, the Reliance "Floating" Motor provides the steel industry with the finest motor of its type ever built. And recognition of it as such has helped to make Reliance the leading supplier!

Reliance "Floating" Motors eliminate any need for couplings and mountings—save valuable space—keep material moving even if rollers warp or the table becomes uneven. Misalignment of motors and rolls is impossible. Maintenance is simplified because motor and roller can be removed as a unit and motor easily removed from roller.

In modern, engineered applications, Reliance D-c. or A-c. "Floating" Motors provide stepless speed changing and quick, smooth starting, stopping and reversing. Write for further important facts or contact your nearest Reliance Application Engineer.

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NOW—

In applications like this one (640 motors on runout tables and conveyors) modern Reliance "Floating" Motors provide adjustable-speeds through the spot conversion of A-c. power.

RELIANCE ELECTRIC AND ENGINEERING CO.

"Motor-Drive is More Than Power" • 1084 Ivanhoe Road, Cleveland 10, Ohio

uated from Coyne Electrical School, Chicago, Ill., and finished several courses in electrical engineering at Pennsylvania State College. He started working in the electrical department of the Standard Steel Car Co., Butler, Pa., and eventually transferred to the Columbia Steel Co. in Butler where he worked on the installation and start-up of the first wide strip mill in 1926. Colum-

W. E. REIBER

bia Steel Co. was then taken over by the American Rolling Mill Co. and he stayed with them until 1930, at which time he went to Great Lakes Steel Corp., Ecorse, Mich. He was appointed assistant chief electrician with them in 1938, and retained that position until his death.

Oakite's New FREE Booklet on Paint Stripping

WHAT'S THE BEST WAY TO STRIP PAINT FROM METAL PARTS TOO LARGE TO BE SOAKED IN TANKS? See Page 3

answers many questions that will lead you to better stripping procedures. You'll want to read more about:

What's the best way to strip large areas of structural metal where a steam supply is available? *See page 5.*

What's best when steam is not available? *See page 7.*

What is the cheapest way to strip metal parts in large volume? *See page 9.*

What are the best ways to prepare stripped surfaces for repainting? *See page 11.*

What strippers are best for removing oil-base paints? . . . Synthetic enamels, alkali-resistant plastics or resin-based paints? . . . Japans, wrinkle finishes, nitrocellulose lacquers, alkyds, phenolics and ureas? *See page 12.*

FREE For a copy of "How to STRIP PAINT" write Oakite Products, Inc., 19 Thames Street, New York 6, N. Y.

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OAKITE SPECIALIZED INDUSTRIAL CLEANING MATERIALS • METHODS • SERVICE

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- **FALCON COOLING PLATES**, both Bosh and Inwall—because they are made without those leak producing anchors and chaplets.
- **FALCON PLATES** are all cast without anchors and chaplets—one homogeneous casting with uniform wall thicknesses.

FURTHERMORE, THEY ARE CAST VERTICALLY WHICH INSURES THE DENSEST, MOST SOLID POSSIBLE METAL, IN THE NOSES . . . . . .

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- **FALCON BAFFLE ARRANGEMENTS** provide maximum circulation of cooling water and the elimination of sediment deposits.
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YOUNGSTOWN 3, OHIO

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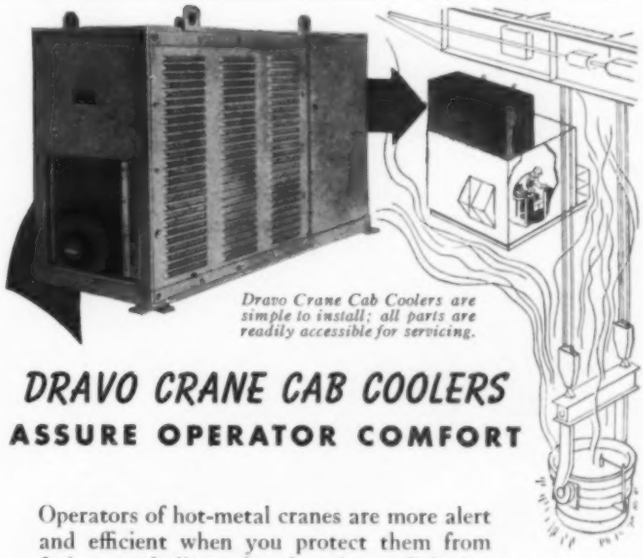

Dravo Crane Cab Coolers are simple to install; all parts are readily accessible for servicing.

DRAVO CRANE CAB COOLERS

ASSURE OPERATOR COMFORT

Operators of hot-metal cranes are more alert and efficient when you protect them from fatigue and discomfort by air conditioning the cabs with Dravo Crane Cab Coolers.

Completely self-contained, and requiring only an electrical connection, the Dravo Crane Cab Cooler provides complete air conditioning:

Cooling	Continuous Ventilation
Fume and Odor Removal	Dehumidifying
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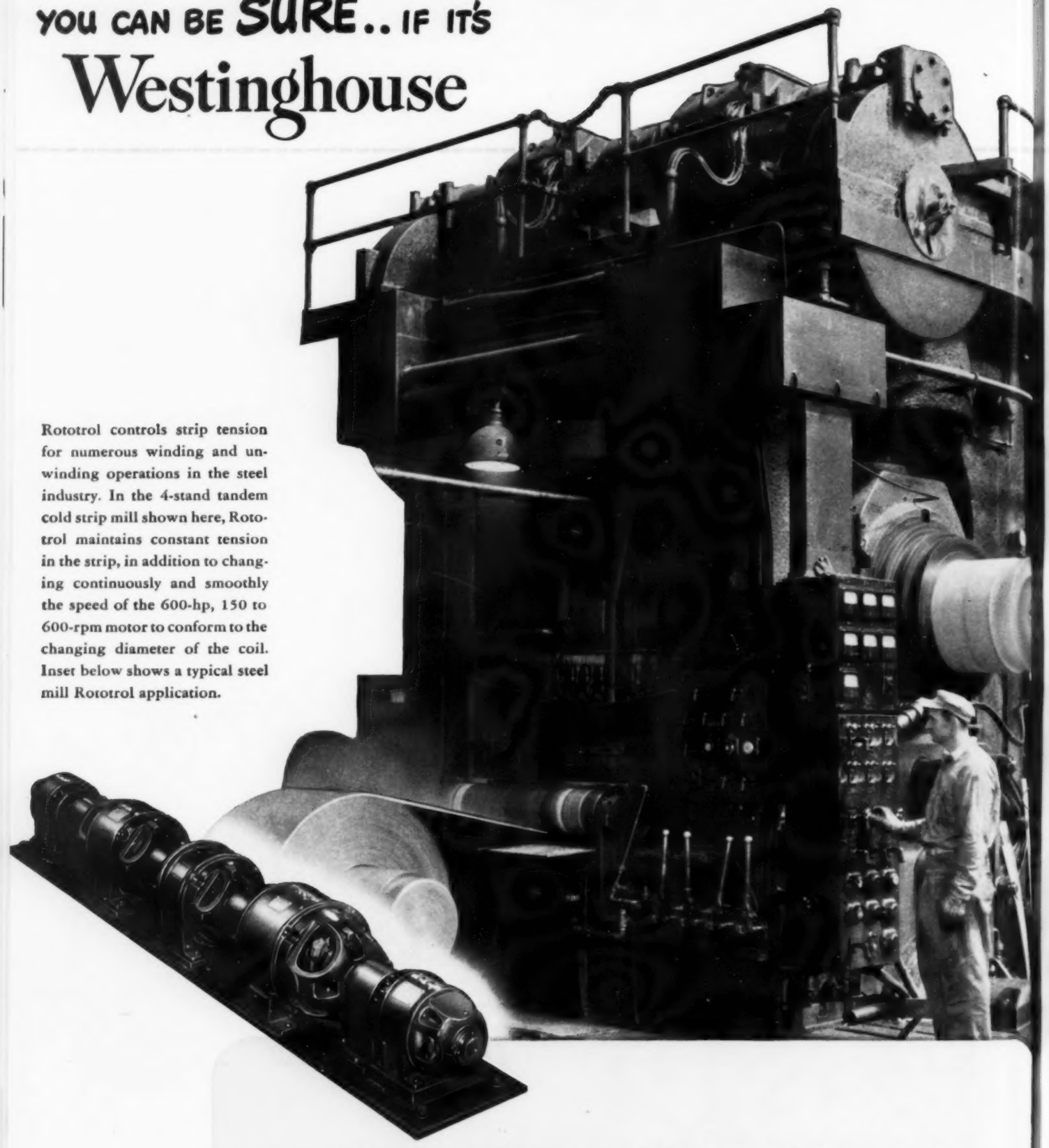
YOU CAN BE **SURE**.. IF IT'S

Westinghouse



Rototrol controls strip tension for numerous winding and unwinding operations in the steel industry. In the 4-stand tandem cold strip mill shown here, Rototrol maintains constant tension in the strip, in addition to changing continuously and smoothly the speed of the 600-hp, 150 to 600-rpm motor to conform to the changing diameter of the coil. Inset below shows a typical steel mill Rototrol application.

INTERACTION OF FIELDS DOES IT ALL

The Westinghouse Rototrol is made exactly like a small, d-c generator, except for several additional field windings. It functions entirely through the smooth interaction of these fields.

Having no mechanical—and very low electrical—inertia, Rototrol responds quickly to deliver the required control power. It brings new standards of perfect performance to almost any repetitive process in the steel industry.

The simplicity of operation makes the Rototrol easy to maintain. It gives unvarying performance indefinitely. It is easily serviced by nontechnical men, and its rugged construction stands up superbly to the rigors of steel mill use.

J-94286

Where else can YOU use ROTOTROL to speed up steel production?

Rototrol—the electrical intelligence—has an outstanding record of accomplishments in the steel industry. By providing smoother, more accurate control of a wide variety of steel processes, it has brought increased production and lower costs.

Here are some of the jobs it is doing:

for skip hoist drives—regulates speed better . . . widens speed range . . . simplifies control.

for blooming mill drives—forces action . . . brings faster, smoother reversals.

for tandem cold strip mills—improves control over stand speeds, acceleration, slowdown and stopping.

for processing lines—matches speed . . . makes possible more rapid acceleration and deceleration . . . minimizes necessary down time.

for flying shear—combined with electronic control, matches speed of shear with that of the mill . . . cuts to close tolerances . . . reduces maintenance costs.

for runout tables and coilers—matches table and coiler speeds accurately with mill speed . . . simplifies operation.

for a-c and d-c generators—regulates voltage . . . holds voltage to preset values . . . returns immediately after changes in loading.

for twin-motor drives—balances load . . . eliminates complex electrical connections.

for rod mills—combined with electronic regulators, matches motor speeds accurately . . . virtually eliminates impact speed drop.

for piercing mill drives—controls stability . . . enables motor to carry high peak loads without pull-out . . . often reduces size and cost of motor needed.

for arc furnaces—regulates power . . . changes electrode position quickly and accurately . . . reduces electrode breakage.

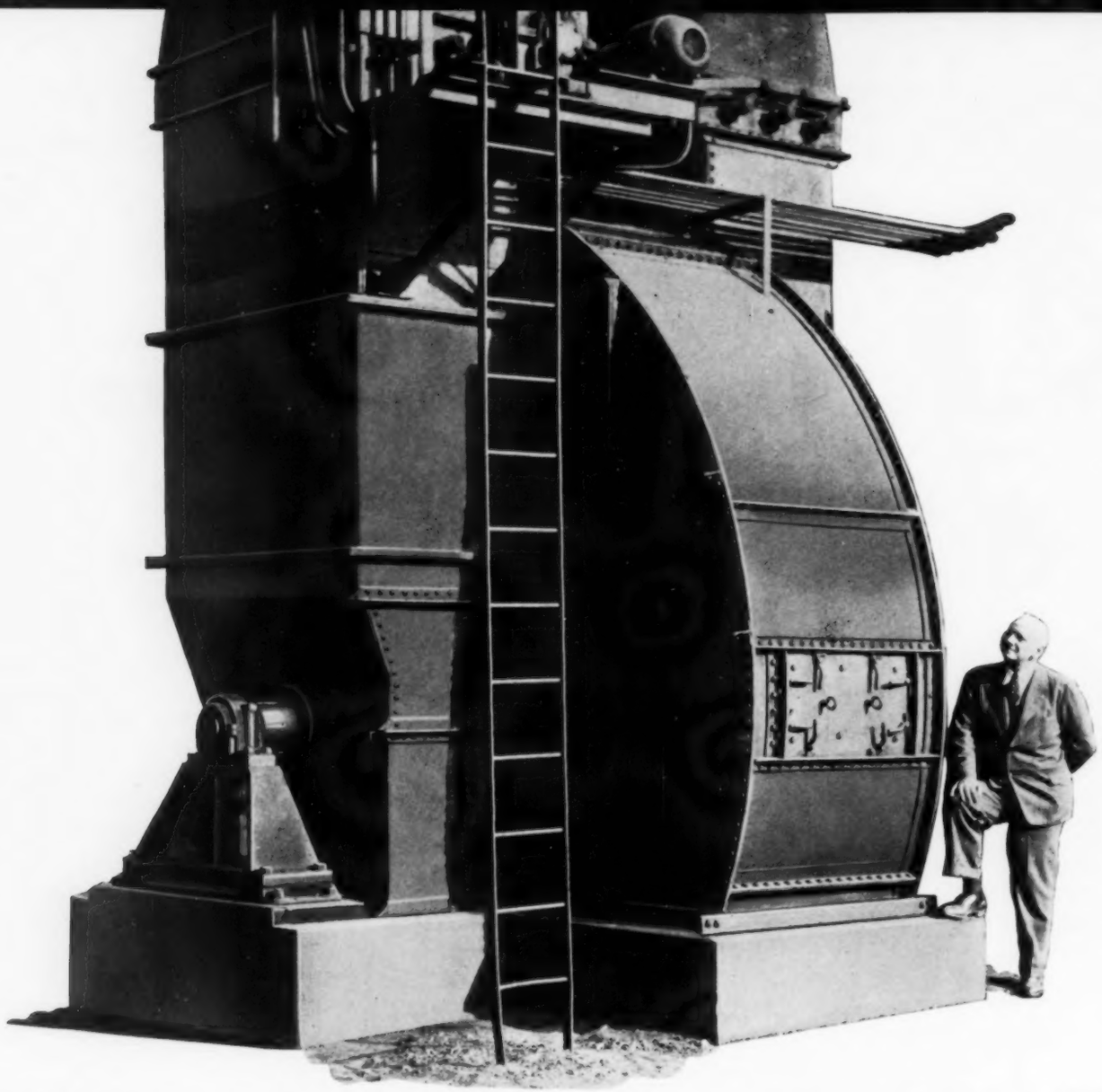
for synchronous motors—regulates voltage automatically . . . adjusts excitation . . . improves power factor.

These applications are suggesting even further uses for Rototrol in the steel industry. There is no foreseeable limit to the improvements possible in steel production methods through better electrical control.

Let Westinghouse applied engineering help you develop and apply new methods and equipment for your specialized requirements. Westinghouse specialists in steel industry applications will be glad to work with your own engineers in studying your operations. Westinghouse Electric Corporation, P. O. Box 868, Pittsburgh 30, Pa.

"ROTOTROL IN THE STEEL INDUSTRY"
This 24-page booklet tells the complete story of Rototrol in the steel industry; its functions . . . its applications . . . its remarkable accomplishments as a control for steel-producing machinery. Ask your nearest Westinghouse District Office for a copy of B-3998.

Westinghouse



PRESSURES—from 10″ to 20″ of water HEAT—300° to 500° F

—YET "Buffalo" SINTERING FANS *Can Take It!*

—Just One of Many Special "Buffalo" Fans

DURABILITY is at the top of the list of qualities to look for in a sintering fan. Continual heat, high pressures and erosion take a heavy toll of rotors and housings.

Yet "Buffalo," builder of fans for 72 years, knows how to build durability into such fans. Blades and housing are extra heavy plate, shafts and bearings are extra sturdy. Construction permits accessibility to all fan parts for quicker inspection, servicing or ultimate replacing of worn parts. The sintering fan is just one of many "Buffalo" fans for the iron and steel industries.

For corrosive fume removal, pressure blowing, mill motor cooling, there's a "Buffalo" Fan with just the performance characteristics you want — for efficiency, long life and economy. *WRITE FOR BULLETIN 3750 and investigate.*

"Buffalo" FIRST FOR FANS

BUFFALO FORGE COMPANY

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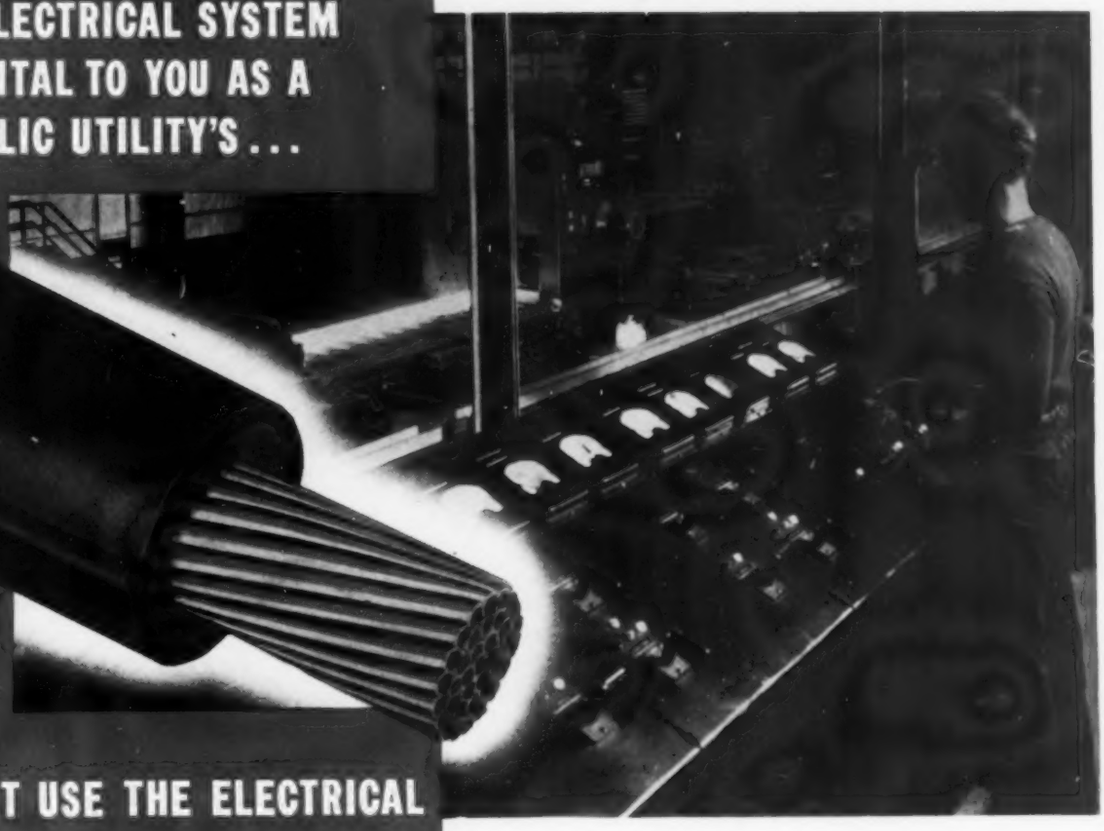
YOUR ELECTRICAL SYSTEM IS AS VITAL TO YOU AS A PUBLIC UTILITY'S . . .



. . . WHY NOT USE THE ELECTRICAL CABLE THE PUBLIC UTILITIES USE?

Many steel mills maintain an electrical system as large and as vitally important as a public utility's. In any system that demands freedom from power interruptions, your safest buy for any circuit is a cable of the highest quality. Okolite-Okoprene is so regarded by public utilities, who consider it the most reliable and economical when all factors are considered.

Okolite-Okoprene is designed to withstand damaging elements of the kind found in steel mills. It is highly resistant to attack from chemicals used in fluxing, refining, pickling and desulphurizing . . . from lubricating oils and cutting compounds . . . from flame and high heats . . . and by mechanical damage.

As your guarantee of the highest possible electrical performance, the basic insulation is Okolite – made with natural Wild Up-River Fine Para rubber to obtain the optimum dielectric and aging properties.

The tough, expertly compounded Okoprene covering substantially contributes to the remarkable staying power of Okolite-Okoprene. Both the long-lived Okolite insulation and the Okoprene sheath are vulcanized simultaneously in a continuous metal mold. Together, these components represent years of cable research and manufacture and a performance record in the field exceeded by no other neoprene-jacketed cable.

Ask your local utility engineer about Okonite cables. He knows the familiar Okonite ridge on cable means long years of trouble-free service. The Okonite Company, Passaic, N. J.

THE BEST CABLE IS YOUR BEST POLICY

OKONITE OKONITE SINCE 1878 *insulated wires and cables*

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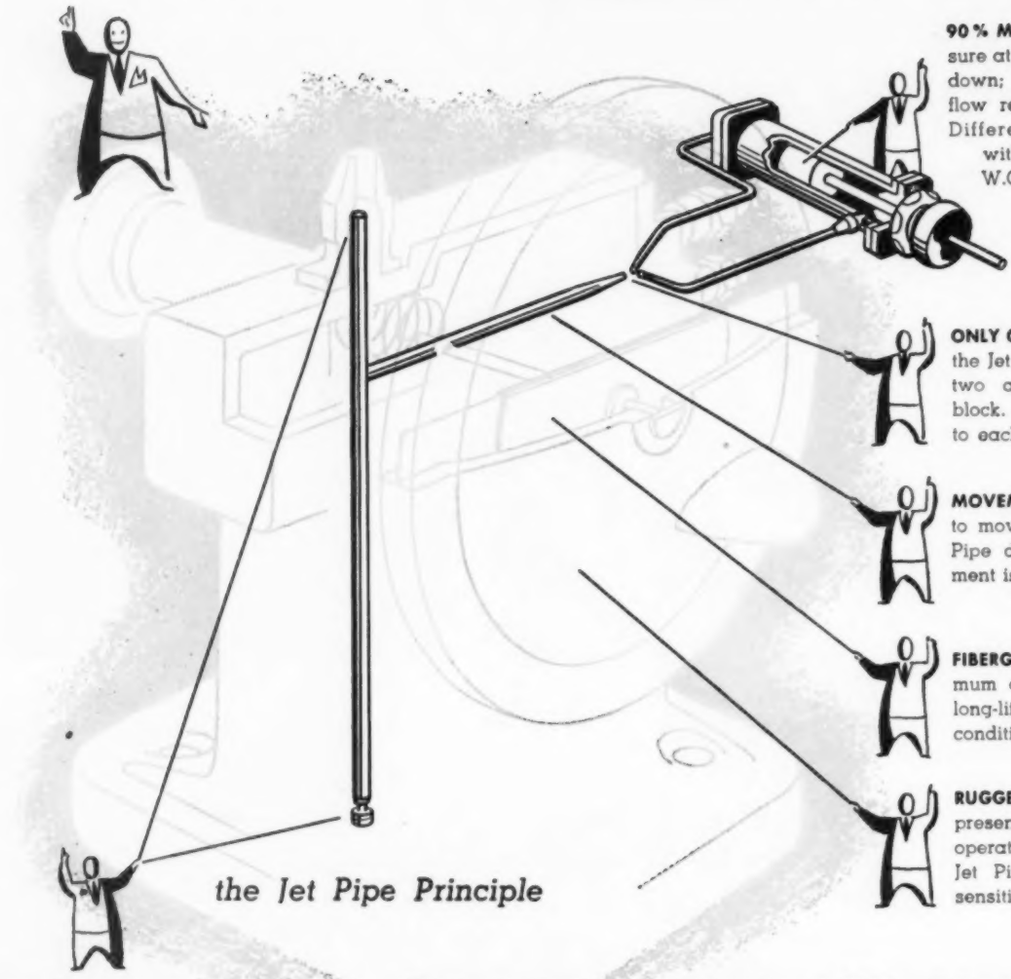
Here's Why You'll Like

Askania Controls



the Jet Pipe Principle

90% MAXIMUM RECOVERY of inlet pressure at operating cylinder; 10 to 1 turndown; 1% accuracy over range; (i.e., flow regulator designed for 3" W.C. Differential Pressure would control within an accuracy of ±.03" W.C.).

ONLY ONE MOVING PART in the relay—the Jet Pipe—which discharges oil into two adjacent orifices in distributor block. One of the orifices is connected to each side of piston.

MOVEMENT OF JET PIPE causes piston to move at a rate proportional to Jet Pipe deflection. Total Jet Pipe movement is less than one degree.

FIBERGLAS DIAPHRAGM presents maximum of sensitivity with maximum of long-life, detects changes of operating conditions as small as .0025" W.C.

RUGGED CONSTRUCTION of regulator presents best possible protection for operation of single moving part—the Jet Pipe, combining sturdiness with sensitivity and accuracy.

JET PIPE needs support at only two points, upper and lower bearings, by fitted connections always bathed in oil to provide constant lubrication and prevent friction (oil flow enters Jet Pipe at top inlet bearing).

THESE SIX POINTS add up to why you'll like Askania Controls. Accuracy, sensitivity, stability, simplicity, ruggedness, maintenance-free operation: all points you can be sure of when you specify Askania Control. The reason for this is the Jet Pipe, heart of all Askania Regulators, a simple, accurate relay with only one moving part. By the Jet Pipe Principle, minute pressures or signals from the source of measurement are amplified into a powerful force.

For tough control jobs . . . for applications where dependability is all important . . . for processes requiring extreme accuracy, Askania Jet Pipe Controls are the ideal answer.

Ask for Bulletin 139J

ASKANIA Controls

ASKANIA REGULATOR COMPANY

A Subsidiary of General Precision Equipment Corporation

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God bless you, mister

...thousands of Cancer patients are grateful to you!

Cancer's annual toll of 200,000 lives is grim proof of the need for your continued generosity. The money you contribute to the American Cancer Society helps pay for the development of methods of treatment which are now saving about one-quarter of the people who are stricken with Cancer... people who might otherwise have died. Your money supports the work of more than a thousand specialists who are fighting to find the cause and cure of Cancer. And it finances a vast education program that trains professional groups, tells the public how to recognize Cancer and what to do about it.

Your life—the life of everyone you know—is at stake. Your investment can mean health and happiness to millions. Thank you... and God Bless You, Mister.

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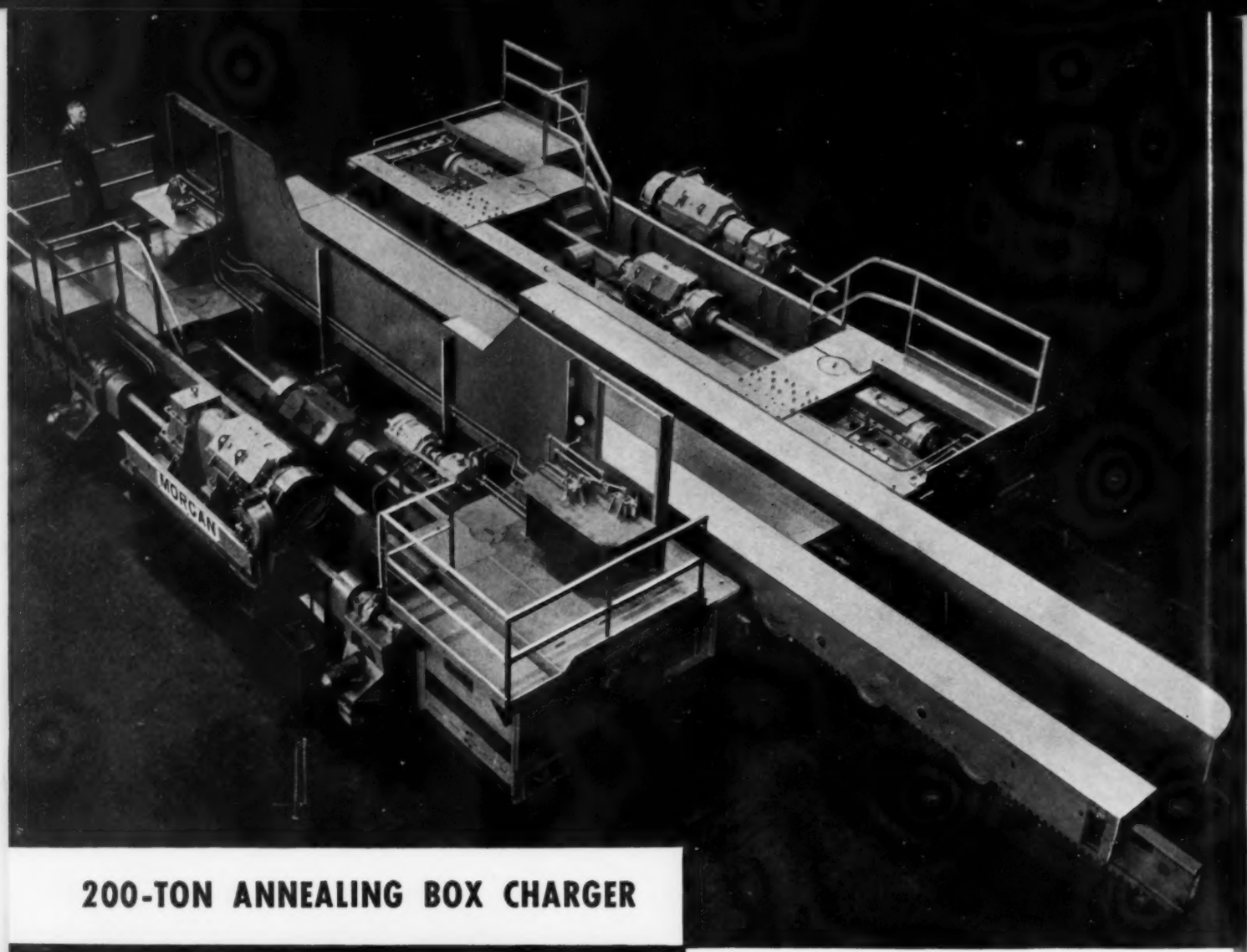
CANCER

Just write "CANCER" on the envelope containing your contribution. It will be delivered to the American Cancer Society office in your state.



200-TON ANNEALING BOX CHARGER

BUILT BY MORGAN Engineering

Illustrated is a Morgan 200-Ton, 5-motor, 19'-3½" Span Annealing Box Charger. It consists of a traveling bridge upon which are mounted two rack driven charging trucks operating in unison for raising the annealing boxes and moving them into or out of the furnace or onto the cooling beds. The charging trucks are operated by two motors through four worm units with provision for operating either of the two motors alone.

THE MORGAN ENGINEERING CO.

ALLIANCE, OHIO PITTSBURGH—1420 OLIVER BUILDING

DESIGNERS • MANUFACTURERS • CONTRACTORS • BLOOMING MILLS • PLATE MILLS • STRUCTURAL MILLS • ELECTRIC TRAVELING CRANES • CHARGING MACHINES • INGOT STRIPPING MACHINES • SOAKING PIT CRANES • ELECTRIC WELDED FABRICATION • LADLE CRANES • STEAM HAMMERS • STEAM HYDRAULIC FORGING PRESSES • SPECIAL MACHINERY FOR STEEL MILLS

Equipment News...

THE APPLICATION OF RAILWAY ROLLER BEARINGS TO MOTOR CHANGEOVERS

By A. A. VAN PELT
Van Pelt Electric Co.
Pittsburgh, Pa.

▲ One of the most immediate fields in which the Van Pelt maintenance series railway roller bearings should prove of exceptional value to the maintenance departments in all steel mills, coal mines and heavy industry in general, is their application to mill and crane motor changeovers. Naturally their use is not limited to mill and crane motors only, as many other general purpose motors will also come in for their share of attention.

Up to the present time it has been necessary to either weld up or metallize quite a number of shafts or to buy new shafts for quite a large number of different sizes of motors. One very popular line of motors for changeover has been the Westinghouse "K" series, in which the K-3, K-4, and K-7 shafts had to be built up. The K-3 and K-4 motors had journal diameters of 1.750 in., with negative tolerance, and the nearest bearing size with a bore of 45 mm required the journal diameter to be built up to 1.7724 in.

The K-7 journal diameter of 2.500 in. had to be built up to 2.5600 in. diameter for a 65 mm bore bearing, or to 2.5009 in. for an inch bore bearing.

For their MC series the same conditions as above existed for the MC-30 size, while the P.E. of the MC-103 had a very severe problem with a 5¾ in. journal diameter.

The older Westinghouse MT series had similar problems as the MC, only when it came to the MT-161, and MT-162 sizes the problem was more acute, as the shafts were really getting big.

For the General Electric CO-1800 series crane motors the journal diameters were practically no problems for roller bearing application, but in the MD-100 series and the MI-100 series the problems were considerably more severe.

The above are just a few specific notes on individual sizes in various series, but in order to show exactly the welding or metallizing necessary, and on which motors it is required, we have worked up the accompanying tabulation which shows the motor size, original journal diameter, shaft diameter necessary for nearest available size of bearing (ball or roller), and the exact net amount of weld metal which must be applied to the shaft.

It should be noted that the Van Pelt maintenance series of roller bearings is most desirable primarily for shafts having tapered extensions. There was a time when many of the older shafts were built with a "straight" extension, which provided no variation whatever between the journal diameter and the straight extension diameter. For instance the journal diameter and the shaft extension diameter of a Crocker-Wheeler EW or FW were 4.000 in. + .0000 in. —.0005 in. straight through. Since a regular 4 in. bore roller bearing requires a seating diameter of 4.0011 in. it becomes necessary to enlarge the shaft diameter, in the journal section, to this amount.

The present accepted method of doing this work is to metallize the shaft to slightly above the necessary diameter, and grind back to the desired dimension.

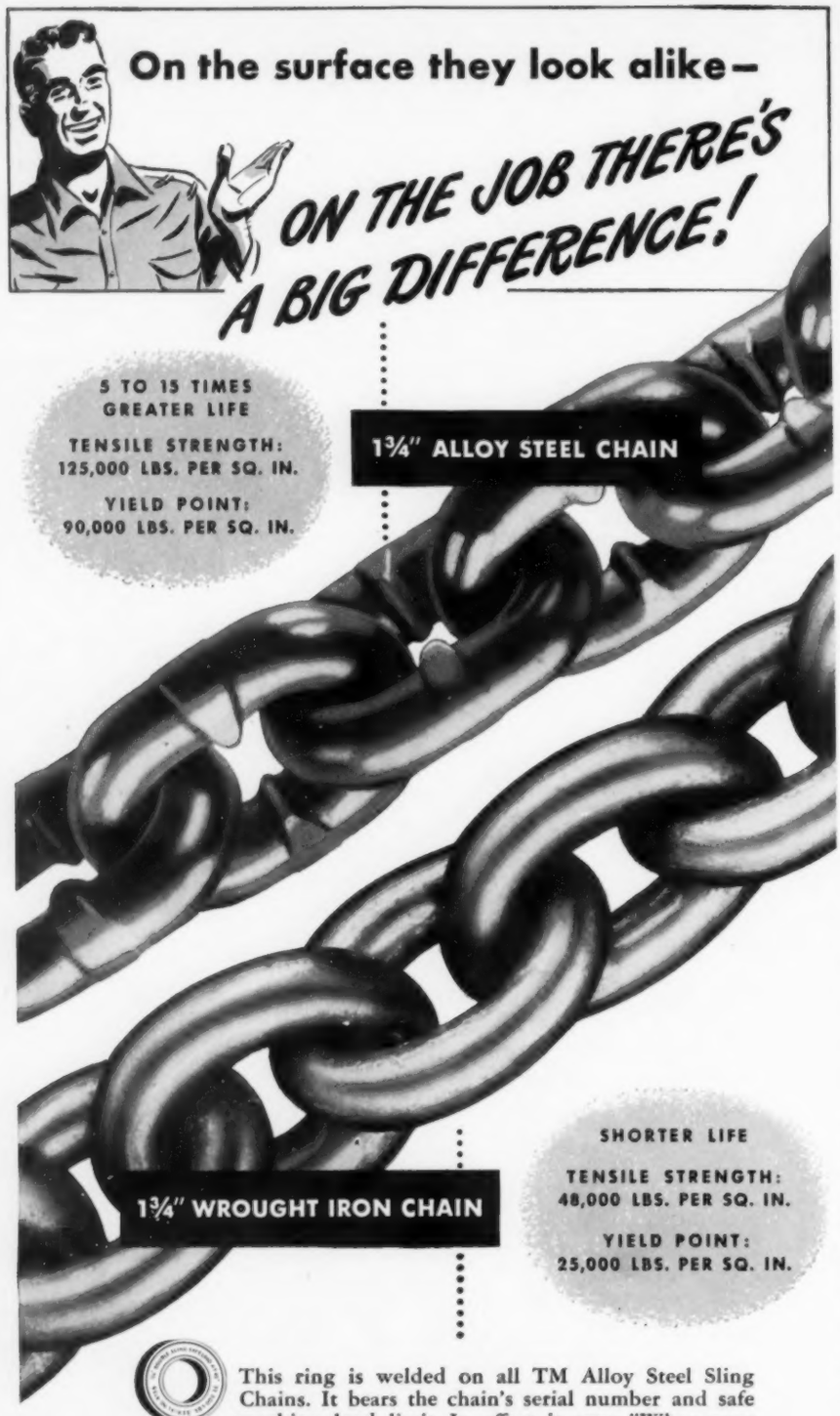
MACHINING REQUIREMENTS ON MOTOR SHAFTS
NECESSARY FOR CHANGING OVER TO ROLLER BEARINGS USING
METRIC, INCH AND VAN PELT MAINTENANCE SERIES ROLLER BEARINGS

Motor Frame	Original Shaft Dia.	Shaft Dia. for Previous Roller Brg.	Net Amt. which had to be added	Recom'd. Shaft Dia. for VPRY Bearings	Net Amount Removed	VPRY Brg. used on shaft in changeover
Westinghouse - Mill & Crane Motors						
K-3	1.750	1.7724	.0224	1.7207	.0293	VPRY-301.720
K-4	1.750	1.7724	.0224	1.7207	.0293	VPRY-301.720
K-7	2.500	2.5009	.0009	2.4709	.0291	VPRY-302.470
MC-30	2.500	2.5600	.0600	2.4709	.0291	VPRY-302.470
MT-00	2.500	2.5600	.0600	2.4709	.0291	VPRY-302.470
Westinghouse - General Purpose Motors						
SK-40	1.750	1.7724	.0224	1.7207	.0293	VPRY-301.720
SK-50	1.750	1.7724	.0224	1.7207	.0293	VPRY-301.720
SK-90	2.125	2.1662	.0412	2.0959	.0293	*VPRY-302.095
SK-120	2.500	2.5600	.0600	2.4709	.0291	VPRY-302.470
SK-130	2.750	2.7566	.0066	2.7209	.0291	VPRY-302.720
SK-160	3.500	3.5444	.0444	3.4711	.0289	VPRY-303.470
SK-170	3.500	3.5444	.0444	3.4711	.0289	VPRY-303.470
General Electric - Mill & Crane Motors						
MD-103	2.500	2.5009	.0009	2.4709	.0291	VPRY-302.470
MD-107	4.500	4.5011	.0011	4.4711	.0289	VPRY-904.470
MD-108	5.000	5.0013	.0013	4.9713	.0287	VPRY-904.970
MD-109	6.000	6.0013	.0013	5.9713	.0287	VPRY-905.970
MD-109 1/2	6.000	6.0013	.0013	5.9713	.0287	VPRY-905.970
MD-110	6.500	6.5015	.0015	6.4713	.0287	VPRY-906.470
MI-103	2.500	2.5009	.0009	2.4709	.0291	VPRY-302.470
MI-107	4.500	4.5011	.0011	4.4711	.0289	VPRY-304.470
MI-108	5.000	5.0013	.0013	4.9713	.0297	VPRY-304.970
MI-109	6.000	6.0013	.0013	5.9713	.0287	VPRY-305.970
Crocker-Wheeler - Mill Motors						
BW	2.500	2.5009	.0009	2.4709	.0291	VPRY-302.470
EW	4.000	4.0011	.0011	3.9711	.0289	VPRY-803.970
FW	4.000	4.0011	.0011	3.9711	.0289	VPRY-803.970
GW	4.500	4.5011	.0011	4.4711	.0289	VPRY-804.470
HW	5.000	5.0013	.0013	4.9713	.0287	VPRY-804.970
IW	5.500	5.5013	.0013	5.4713	.0287	VPRY-805.470

* - Production not contemplated unless demand requires.

SLEWING CRANE ARM SPEEDS CAR LOADING

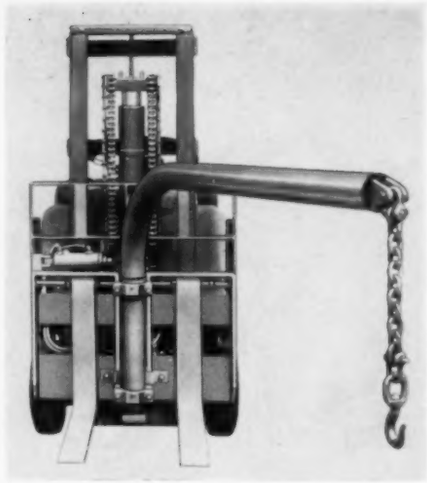
▲ A slewing crane arm, the latest specialized materials handling de-


On the surface they look alike—
ON THE JOB THERE'S A BIG DIFFERENCE!
5 TO 15 TIMES GREATER LIFE
TENSILE STRENGTH: 125,000 LBS. PER SQ. IN.
YIELD POINT: 90,000 LBS. PER SQ. IN.
1¾" ALLOY STEEL CHAIN
1¾" WROUGHT IRON CHAIN
SHORTER LIFE
TENSILE STRENGTH: 48,000 LBS. PER SQ. IN.
YIELD POINT: 25,000 LBS. PER SQ. IN.

This ring is welded on all TM Alloy Steel Sling Chains. It bears the chain's serial number and safe working load limit. In effect it says: "When your lifting requirements are big and your present chain performance leaves something to be desired—it's time to switch to TM Alloy Steel Chain." It's tougher... safer and far more economical than ordinary wrought iron chain. Used by steel, automotive, petroleum, marine and manufacturing industries generally, because *comparison, experience and costs proved its superiority.* For all the facts, write today for free copy of new booklet; "TM Alloy Steel Chain". The S. G. Taylor Chain Company, 61-141st St., Hammond, Indiana.

See your Mill Supply Distributor or send today for free copy of new TM Alloy Steel Chain Booklet!

TAYLOR MADE
A GREAT NAME IN
Chain SINCE 1873



The crane arm is pivoted so it can swing laterally 20 degrees to either side of center.

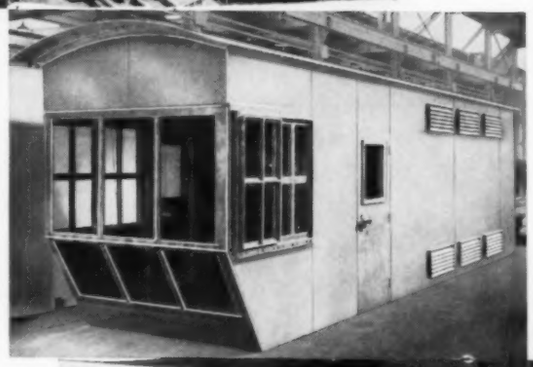
velopment of Towmotor Corp., permits rapid, easy positioning in freight cars of loads up to 800 lb at 80 in. load center. The crane arm is pivoted so that a two-way hydraulic cylinder can swing it laterally 20 degrees to either side of center. The slewing crane arm is readily detachable so that the truck can be used with standard pallet forks.

INSPECTION INSTRUMENTS USE SOUND WAVES

▲ Increasing use is being made of inspection instruments utilizing ultra high frequency sound waves and electrical conductivity principles in connection with electronic amplifiers. A series of these instruments manufactured by the Branson Instrument Co. are designed for measurement of metallic pipe walls, tank walls, boat hulls, etc., when only one surface of the wall is accessible. Another instrument of this group is designed for measurement of nonmetallic coatings, such as paint, rubber, plastics, etc., when applied to a steel base. These instruments are available on a service basis with an operator or are sold by the Maintenance Engineering Corp.

These inspection instruments have been widely used for over five years in steel mills, chemical plants, refineries and in the marine industry to detect and follow the progress of corrosion on hidden surfaces. The insurance companies and inspection services are recognizing the value of these instruments in making nondestructive wall thickness measurements

IN "OPERATION MOTHBALL", NAVY FORESIGHT *Measures up*



An example of one of history's most practical and vital security measures. Brandt is proud of its part as the prime manufacturer of Navy mothball units. Brandt measures up too, to exacting specifications of a wide range of mass produced jobs for government and industry. A bid from Brandt is the right start to save time and dollars. In ferrous or non-ferrous metals. Typical steel-mill jobs include pickling tanks — plain or rubber lined, completely assembled.

STEEL MILL FABRICATED COMPONENTS

Contract Manufacture of

METAL STAMPINGS

HEAVY WELDMENTS

PRESSED STEEL SHAPES

1 Steel mothball unit for Navy gun housing.
2 Steel control and register house for mill.
3 30 ton electrolytic plating tank.
4 Steel Mill Rolling Tables.

IN INDUSTRY—

BRANDT BALTIMORE *Measures up*

TO EXACTING METAL WORKING SPECIFICATIONS

Brandt facilities are all under one roof, strategically located near steel mills, in the midst of major rail, water and highway transportation systems.

CHARLES T. BRANDT, INC., 1700 RIDGELY STREET., BALTIMORE 30, MD.

where the equipment heretofore was drilled and measured manually.

One desirable feature of the Branson instruments is the facility with which they are often used on process equipment while in service. Many applications are found in steel mills in measuring thickness of coke oven flushing liquor lines, process stills, raw water piping, water jackets, pickling equipment, barge and boat hulls, coal bins, etc.

USE THE ENGINEERING MART

HEALTH OFFICIALS USE POLLUTION SAMPLER

By NELSON W. HARTZ

Mine Safety Appliances Co.

▲ Health officials have a new small, simplified instrument for collecting accurate samples of all types of dusts, fumes and smoke in the air. In the sampler, airborne particulates are trapped by electrostatic precipitation as air is drawn through an aluminum collecting tube. The tube then is sealed with plastic caps and the sample is ready for laboratory analysis to determine quantity or quality of the contaminant.

Among the first users of the improved electrostatic sampling equipment were U. S. Public Health Service teams who last year investigated the Donora, Pa. smog tragedy that claimed 21 lives. Developed by the Mine Safety Appliances Co., the instruments played an important role in collecting air samples to determine type and quantity of contaminants in the atmosphere of Donora.

Electrostatic samplers have been adopted by many industries. Now, because of its portability, the electrostatic sampler offers municipal and state health authorities concerned with air pollution an efficient and simple method for collecting atmospheric samples.

The sampling head of the equipment resembles a small hair dryer, weighs only four pounds and is completely self contained. In the head is a blower that provides a constant flow of three cfm of air, and the ionizing electrode that charges incoming airborne particles. An aluminum collecting tube fits into the head around the electrode and is grounded in such a way to attract the charged particles.

The head is connected to a power pack by a 12-foot long high voltage cable. Extension cables can be used for greater freedom of movement. Basically, the power pack is a 60-cycle high voltage transformer to supply the electrode in the sampling head. Its output is rectified through a voltage doubling circuit using two electronic tubes. The power pack can produce regulated voltages from 10,000 to 15,000 volts d-c. Amperage is extremely low, comparable to that of a spark plug. Voltage at the sampling head is accurately measured by a high voltage indicator on the power pack. Three-conductor, grounded supply cord for the power pack can be plugged into any 110/115 Volt outlet.

SPINDLE THREAD IS SELF-LUBRICATING

▲ One of the common but serious complaints against chemical process valves is the corrosion and binding of metal spindle threads. An outstanding feature of National Carbon's "Karbate" impervious graphite globe

Stearns DOES DOUBLE DUTY ON BIG ALUMINUM MILL!

MAGNETIC BRAKES
Positive action of STEARNS Magnetic Disc Brakes prevents overtravel of adjusting screws.
MAGNETIC CLUTCH
Screwdown drives are synchronized with STEARNS Magnetic Clutch.

LEWIS 4-High Foil Mill

Stopping the adjusting screws on a Lewis mill and holding them positively in position is just the job for STEARNS Magnetic Disc Brakes. Designed with a quick, steady pressure that brings a fast stop in the shortest time, STEARNS Magnetic Disc Brakes prevent overtravel of the adjusting screws and thus allow for careful, positive adjustment. Suitable for horizontal or vertical applications, STEARNS brakes are available in sizes up to torques of 575 pounds feet.

Sychronizing the drive on the screwdowns of large mills requires a rugged, dependable clutch — a STEARNS Multiple Disc Magnetic Clutch. For here's a clutch that is constructed of few and simple parts with no toggles, pins, yokes, shifters or other parts to wear and get out of order. Controlled by a push-button station, STEARNS clutches are available with taper-bores, detachable magnet hub and are furnished fully enclosed in a steel housing. Available in torques and construction to meet your screwdown requirements.

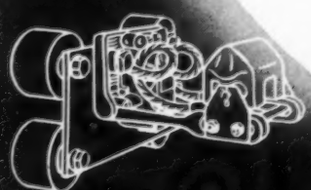
Descriptive literature available. Write today for Bulletin 604-F on brakes, Bulletin 226 on clutches.

Stearns MAGNETIC MANUFACTURING CO.

681 S. 28th St., Milwaukee 46, Wisc.

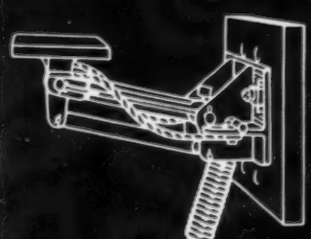
CONTINUOUSLY CONTACTS MAXIMUM RAIL AREA

TYPE LMI
PONY SIZE COLLECTOR . . .



TYPE LMV SPECIAL SHOE

Four insulators; 2" horizontal movement. Other types of special contact shoes also available.



TYPE PS UNDER-RUNNING SHOE

For under-running service. Contact surface approximately 9" wide, 9" long.

NEW KEYSTONE RAIL COLLECTOR . . . EASILY MAINTAINED . . . REVERSIBLE

Want a rail collector designed throughout for efficient and simplified maintenance? Want shoes that have 30% greater travel? Then Keystone Contact Rail Collector Type LMI is your answer.

IMPROVED CONSTANT CONTACT . . . 300% more wearing thickness on each side . . . 26% increase in contact surface area. Large radii on all corners and edges permit shoe to traverse uneven conductor points smoothly . . . less wear.

Solderless shunt connectors and terminals—recessed into ends of shoe to insure long-lived non-loosening electrical connections. Generous bronze terminal clamps shunt and provides solderless connections for a variety of lead sizes.

Adequate alignment provision . . . cool operation . . . efficient current transfer . . . rapid reversal . . . lower overall height . . . reversible . . . these are some of the many features of this new Keystone Contact Rail Collector.

There is a Keystone Contact Rail Collector to meet every requirement of steel mills. Write for Keystone Industrial Products catalog.

TYPE LMV, PONY SIZE SHOE

For V 2" x 2" angle iron contact rails. Two contact surfaces, each 1½" wide, 5" long.

TYPE BI PICK-UP COLLECTOR

For wire conductors. Uses a removable carbon contact member.

ELECTRIC SERVICE MANUFACTURING CO.

1721 CAMBRIA STREET • PHILADELPHIA 32, PENNA.

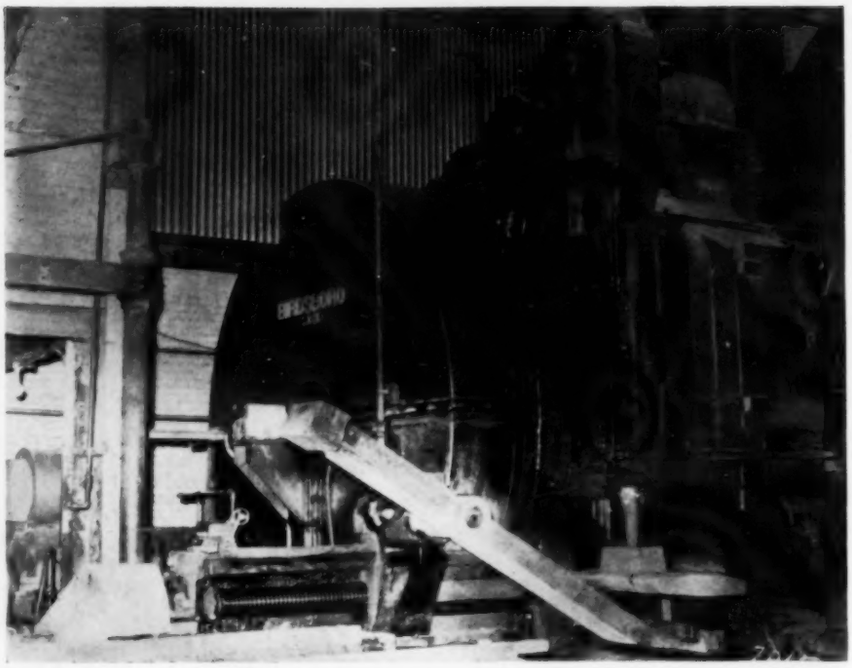
MAKERS OF CONTACT RAIL AND WIRE SUPPORTS, AND COLLECTION DEVICES

Valve spindle after two years' continuous service. Threads are still in excellent condition.

valves is the self-lubricating, corrosion resistant threads on the bonnet and spindle. Users without previous experience with impervious graphite valves are often skeptical of the ability of the spindle threads to stand up under continued use.

Illustrated is a spindle from a 1 in. size valve that has been in continuous service for over two years. This valve was used to fill carboys from a sulfuric acid storage tank and was therefore subjected to complete opening and closing a number of times each day. The spindle threads show a very slight rounding, but are still in excellent condition. The disc on the spindle has worn exactly as expected and continues to reseat itself.

SIMPLE SLAB SHEAR HAS POSITIVE CONTROL



This mechanically simple shear for slab ingots offers a combination of advantages no other single shear possesses, and eliminates many common shearing troubles. It provides (1) positive control of the slab; (2) quick release of sheared slab portions; (3) unobstructed access to shear throat; and (4) reduced maintenance costs through special design features. Originally developed by the Sack Machinery Co. of Dusseldorf, Germany, it is made in this country by the Birdsboro Steel Foundry and Machine Co. It is currently operating in the plant of Rotary Electric Steel Co., Detroit, Mich.

Hyde Park

RED CIRCLE Rolls CHILLED-ALLOY

Rolling Mill Machinery

Mill Shears, Mill Reduction Drives, Roll Lathes, Sheet Pack Carriers, Stretcher Levellers, etc.

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Hyde Park, Pa. (Pittsburgh District)

DEEP CASE GEARS for Your STRIPPER CRANES!

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"IG" DUROCASE GEARS are made to stand the gaff. Deep case hardening does it! Write for details.

Send us your next order and note the difference.

If you would like to see our plant—write for "A Pictorial Trip Through Industrial Gear".

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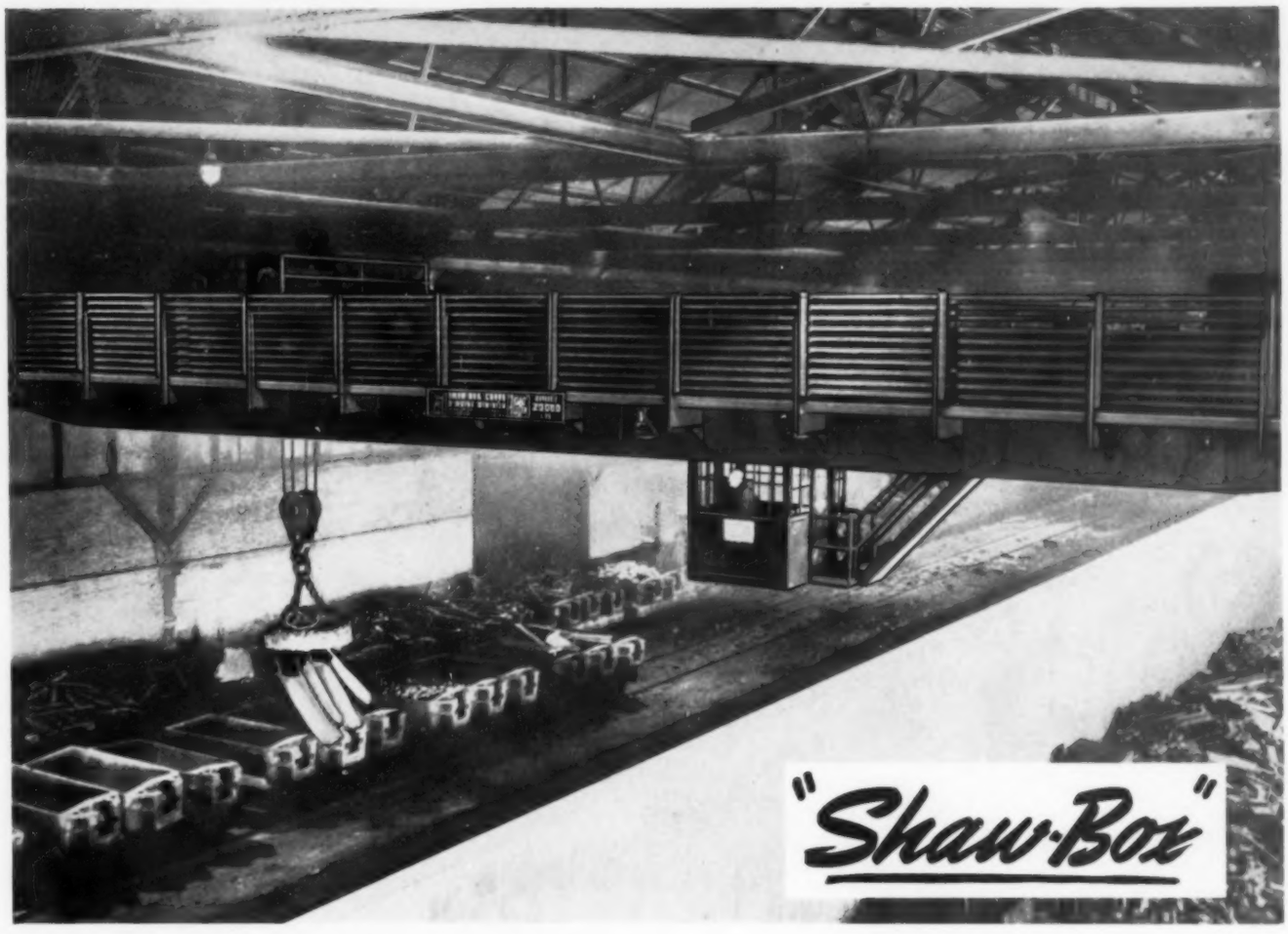


MAGNET HANDLING CRANES

When your magnet handling cranes are "Shaw-Box", you have high-speed, heavy-duty equipment, designed and built to withstand the severe shocks and impacts set up by this service. Simple, rugged, and extremely accessible, they have extra values built into them that insure complete dependability, lowest cost load handling, minimum maintenance, and maximum safety on this tough work.

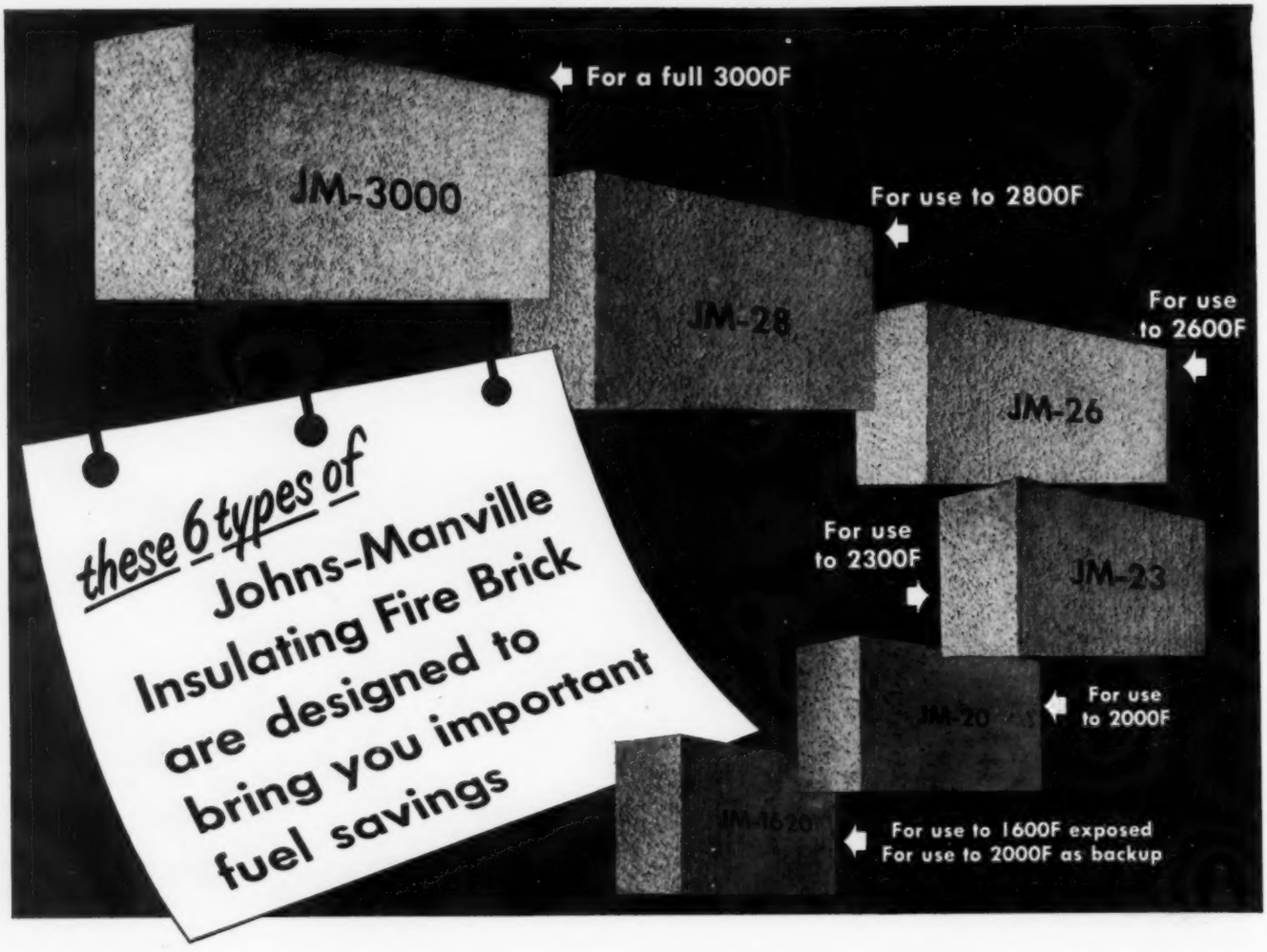
These values result from more than 65 years of pioneering and specialization in interpreting steel-mill crane requirements that have helped develop exacting "Shaw-Box" standards of fine workmanship, engineering, and precision manufacturing methods.

"Shaw-Box" Magnet Handling Cranes fully conform to AISE specifications. They are engineered to withstand the most exacting demands with minimum wear and time out of service, even under the most unfavorable conditions. They are recognized for these qualities in mills all over the country. That is why, for the work they do, they are the greatest value in dependable crane service your dollar can buy.

Be sure to send all your inquiries for Steel Mill Cranes and Magnet Handling Cranes to "Shaw-Box."

MANNING, MAXWELL & MOORE, INC.
SHAW-BOX CRANE & HOIST DIVISION
MUSKEGON, MICHIGAN

Builders of "Shaw-Box" Cranes, 'Budgit' and 'Load-Lifter' Hoists and other lifting specialties. Makers of 'Ashcroft' Gauges, 'Hancock' Valves, 'Consolidated' Safety and Relief Valves, 'American' Industrial and 'Microsen' Electrical Instruments.



You can make important savings in fuel by taking advantage of the quick heating characteristics of J-M Insulating Fire Brick. These light-weight brick permit a quicker rise to proper operating temperature in the furnace because of their low heat storage capacity, and low thermal conductivity. Where furnaces are being intermittently operated these are two especially important characteristics.

These same insulating materials can also be obtained in large size units called Johns-Manville Insulating *Fireblok*. This product has many advantages over the smaller size fire brick for certain types of jobs . . . from both a construction and stability standpoint. The Fireblok units can be quickly applied because they are easy to cut and fit. Fireblok insulations provide additional heat savings because they reduce the number of joints, and require less mortar for bonding.

It will pay you to let a Johns-Manville insulation engineer explain the many ways in which you can save by using these insulations in your furnaces. Just write for further information to Johns-Manville, Box 290, New York 16, N. Y.

JM PRODUCT

	JM-1620	JM-20	JM-23	JM-26	JM-28	JM-3000
Densities, lb per cu ft	29	35	42	48	58	63-67
Transverse Strengths, psi	60	80	120	125	120	200
Cold Crushing Strengths, psi	70	115	170	190	150	400
Linear Shrinkage†, percent	0.0 at 2000 F	0.0 at 2000 F	0.3 at 2300 F	1.0 at 2600 F	4.0 at 2800 F	0.8 at 3000 F
Reversible Thermal Expansion, percent.	0.5—0.6 at 2000 F †	0.5—0.6 at 2000 F	0.5—0.6 at 2,000 F	0.5—0.6 at 2000 F	0.5—0.6 at 2000 F	0.5—0.6 at 2000 F
Conductivity* at Mean Temperatures						
500 F	0.77	0.97	1.51	1.92	2.00	3.10
1000 F	1.02	1.22	1.91	2.22	2.50	3.20
1500 F	1.27	1.47	2.31	2.52	3.00	3.35
2000 F	—	1.72	2.70	2.82	3.50	3.60
Recommended Service						
Back up	2000 F	2000 F	2300 F	2600 F	2800 F	3000 F
Exposed	1600 F	2000 F	2300 F	2600 F	2800 F	3000 F

†24-hr. simulative service panel test for JM-3000; 24-hr. soaking period for other brick.

*Conductivity is expressed in Btu in. per sq ft per F per hour of the designated mean temperatures.

Note: Above tests are in accordance with A.S.T.M. tentative standards.

Johns-Manville *first in* **INSULATIONS**

Get in ALL Your Scrap---Profitably

with OXWELD Equipment

Trade-Mark

Here's the OXWELD *C-60 Cutting Blowpipe in action . . . slicing up a steel button 6 ft. thick with ease!*

Oxygen cutting rapidly converts steel sections of every size, shape, and type into good, usable scrap. Any thickness is easily reduced to charging-box size with OXWELD equipment. And no job is too tough. Whatever your scrap-cutting problem, there's an OXWELD blowpipe to solve it efficiently and economically.

For the extra-heavy jobs, the OXWELD C-60 Cutting Blowpipe with powder-cutting attachment is the answer. Especially engineered for cutting spills and ladle skulls, this combination easily makes continuous cuts through 6 ft. of dirty, slag-incrusted steel.

Other highly adaptable OXWELD blowpipes speed up medium scrapping operations. Mounted on portable, lightweight machines, they work on a production basis, cutting ingots, castings, and risers into sizes convenient for charging into the furnace.

On the lighter jobs, sturdy OXWELD hand-cutting blowpipes ready steel scrap up to 12 in. thick for the charging box. With 57 different nozzles to choose from, you get maximum efficiency at lowest overall cost.

LINDE has accumulated a vast amount of practical experience in helping to solve many unusual scrapping problems. If you have a scrap-cutting problem, ask our nearest office for help. We have the know-how, the "show-how," and everything you need to do the job profitably.

The term "Oxweld" is a registered trade-mark.

THE LINDE AIR PRODUCTS COMPANY

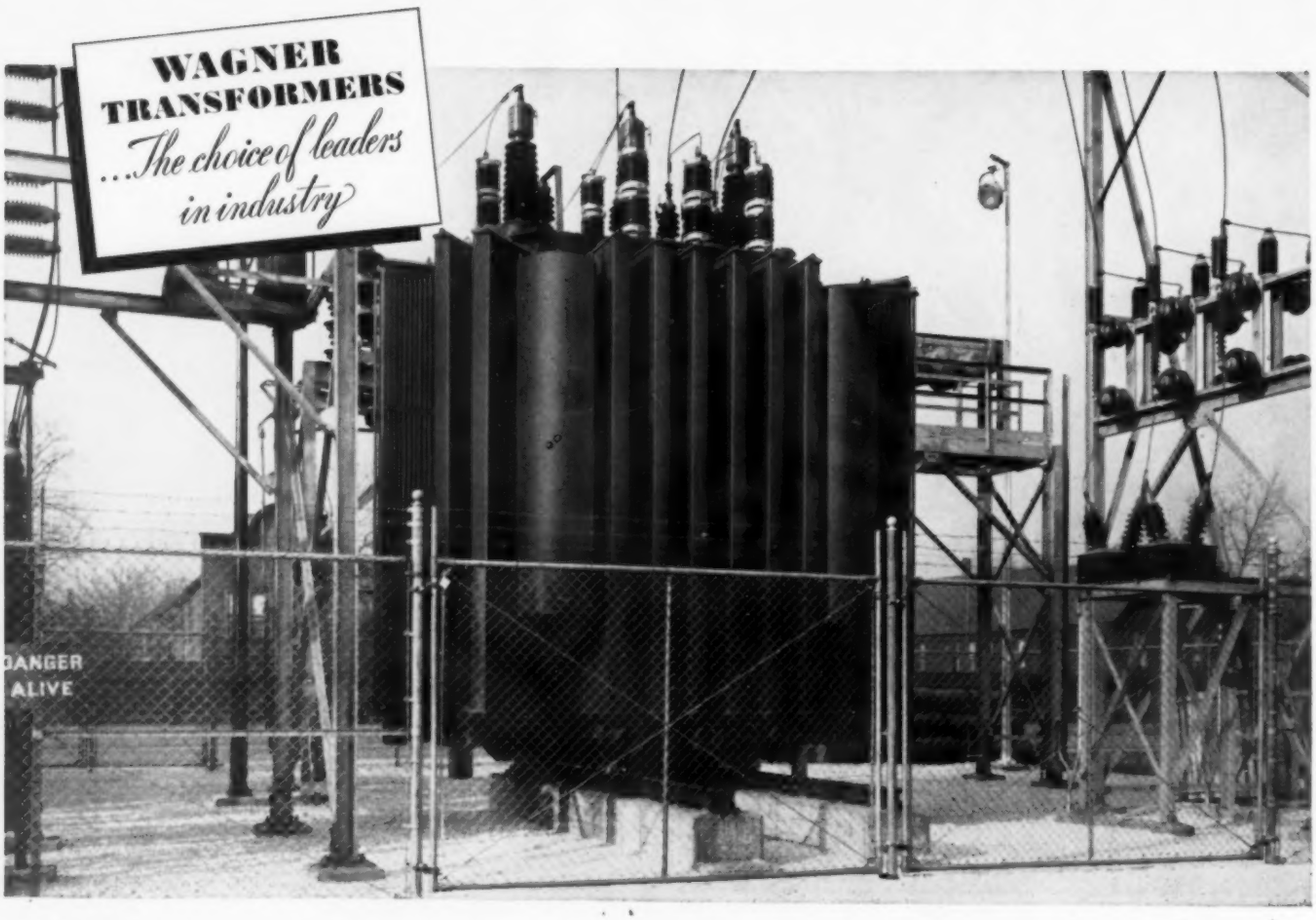
Unit of Union Carbide and Carbon Corporation

30 E. 42nd St., New York 17, N.Y. Offices in Other Principal Cities

In Canada: Dominion Oxygen Company, Limited, Toronto

A lightweight OXWELD *portable machine speeds this scrap-cutting operation. Setup is semi-automatic and portable . . . can be easily moved from one job to another.*

Spills, salamanders, and other mill scrap can be cut quickly and efficiently with an OXWELD *hand-cutting blowpipe . . . and with minimum gas consumption.*



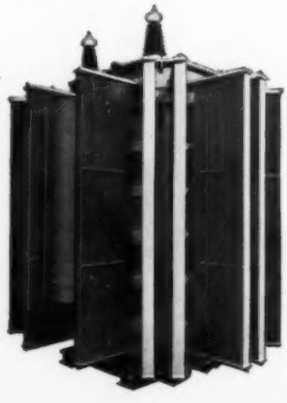
Wagner Transformers provide Carnegie-Illinois Steel dependable distribution of power to *"keep 'em rolling"*

When you think of the Carnegie-Illinois Steel Corporation, you may have a mental picture of the greatness of American industry. It *is* great—a modern goliath of industrial production—rolling out the steel that is the sinew of all industry. And its greatness is in *production.*

Production is a word with which Wagner Transformers like to be associated. Hundreds and hundreds of Wagner power transformers, of all types and sizes are distributing power to industrial plants throughout the country. In every case they are adding to their reputation for complete dependability . . . for unfailing service . . . that prompted Carnegie-Illinois to install Wagner Transformers.

Wagner engineers are qualified to specify the correct transformer for *your* requirements. Nationwide service facilities are available to users of Wagner Transformers. Consult the nearest of our 31 branch offices or write us.

Shown below is a Wagner 16,667 kva Power Transformer. Single phase, 60 cycle, 72,000 to 6,600 volts. This transformer was adapted to the special needs of the Carnegie-Illinois application. Wagner engineers can suit your special requirements as well.



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6483 Plymouth Ave., St. Louis 14, Mo., U.S.A.

Wagner Electric Corporation
EST. 1891

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AUTOMOTIVE BRAKE SYSTEMS — AIR AND HYDRAULIC

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THE ENGINEERING MART

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For application to soaking pits, heating, and other types of metallurgical furnaces.
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An Affiliate of CHEMSTEEL CONSTRUCTION CO., INC.
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• Complete facilities for corrosion-proof construction of processing & storage tanks: Design, Engineering, Materials, Construction, Maintenance.
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THOMAS—Flexible Couplings
SMITH—Telesmith Crushers
CULLEN-FRIESTEDT—Sheet Lifters—Welding Positioners—Track Cranes

for ACID-PROOF TANKS
SAUEREISEN ACID PROOF CEMENTS

Years of dependable service in leading steel mills, chemical plants, etc. A type for every acid proofing use.
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TELEPHONE: Whitmore Lake 5931

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WANTED
Dominion Foundries & Steel, Ltd., Hamilton, Ontario, are building a new blast furnace and coke oven plant and have good position open for operating superintendent. Technically trained applicants will receive preference but anyone applying must be fully experienced. Apply to F. A. Loosley, Vice-President.

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Book Reviews

▲ THE ROLLING OF METALS, Theory and Experiment, Vol. 1 by L. R. Underwood, has just been published by John Wiley & Sons, Inc., 440 Fourth Avenue, New York 16, N. Y., 344 pp., 9 × 5¾ in., price $6.50. The first volume of this book gives a critical account of the principles of rolling flat metals as determined by theoretical experimental investigations and as determined by the author in a research paper prepared for the Rolling Mill Research Subcommittee of the British Iron and Steel Federation. This book covers the more fundamental aspects of the subject such as forward slip, friction between rolls and material, and friction hill theories of rolling and the methods of calculation of the rolling load based upon them. Volume Two which is yet to be published deals with lateral spread and practical methods of calculating roll load and horsepower. The book should be of value to rolling mill engineers and operators.

▲ HEATING VENTILATING AIR CONDITIONING GUIDE 1950, 28th edition has been recently published by the American Society of Heating and Ventilating Engineers, 51 Madison Avenue, New York 10, N. Y., 1422 pp., 9 × 6 in., price $7.50 per copy. This edition has been brought up to date by including the recent developments in the technical field in accordance with the latest suggestions on the part of the users. The book is widely used as the standard handbook in the field.

▲ THE PROPERTIES OF METALLIC MATERIALS AT LOW TEMPERATURES by P. Litherland Teed, 222 pp., 8¾ × 5½ in., price $3.50 has recently been published in the United States. This book is volume 1 in a series of monographs published under the auspices of The Royal Aeronautical Society. This book is a critical survey of a large number of experiments for unfortunately, it is still impossible to predict what will happen to a metal at one temperature by using data collected at another temperature. The data given in this book is, therefore, of value to those men selecting materials for use in low temperature ranges. Book may be obtained from John Wiley & Sons, Inc., 440 Fourth Avenue, New York 16, N. Y.

▲ INELASTIC BEHAVIOR OF ENGINEERING MATERIALS AND STRUCTURES by Alfred Freudenthal, 587 pp., 8½ × 5½ in., price $7.50, has been recently published by John Wiley & Sons, Inc., 440 Fourth Avenue, New York 16, N. Y. The book develops a fundamental and technical approach to materials research and understanding, by concentrating on the behavior of materials by establishing concepts based on the laws governing the formation of matter from particles. This development helps in the better understanding of the more common properties of materials. The approach is advanced and mathematical.

▲ INDUSTRIAL INSTRUMENTATION by Donald P. Eckman has recently been published by John Wiley & Sons, Inc., 440 Fourth Avenue, New York 16, N. Y., 396 pp., 247 illustrations, 5⅝ × 8⅝ in., price $5.00. The book reviews the principles of measurement methods employed in industrial processing and manufacturing. The book is informative in that the method rather than the mechanism is covered, and the treatment is basically analytical rather than empirical. The book covers in detail qualities of measurement, expansion thermometers, resistance thermometers, radiation temperature measurement, methods for composition analysis, mechanical measurement of pressure and vacuum, heads and levels, flowmetering and process instrumentation.

▲ HANDBOOK OF EXPERIMENTAL STRESS ANALYSIS edited by M. Hetenyi, which has been recently published by John Wiley & Sons, Inc., 440 Fourth Avenue, New York 16, N. Y., 9¼ × 5⅞ in., 1076 pp., price $15.00, comprises the most complete presentation of experimental methods for the determination of mechanical strength and stress which has yet been presented. This book was written by outstanding stress analysis men, and each subject was covered by experts in that particular field. This field is relatively new and many developments have been brought out in the last few years. By compiling all of these in one book, a definite service has been rendered to the design engineer.

INDEX TO ADVERTISERS

A

Aetna-Standard Engineering Co., The 1
Air Reduction Sales Co. M-36
Alliance Machine Co., The 15
American Air Filter Co., Inc. 137
American Bridge Co. M-41
Askania Regulator Co. 148

B

Bailey Meter Co. 132
Bantam Bearings Division of The Torrington Co. M-27
Bedford Foundry and Machine Co. 138
Birdsboro Steel Foundry and Machine Co. 32
Bloom Engineering Co. 127
Bonnot Co., The M-25
Brandt, Inc., Charles T. 153
Brosius Co., Edgar E. 120
Browning and Co., Inc., Victor R. 141
Buffalo Forge Co. 146

C

Cities Service Oil Co. 139
Clark Controller Co. 23
Cleveland Crane and Engineering Co. M-32, M-33
Cleveland Worm and Gear Co., The ..... Cover 3, Cover M-3
Columbia Electric Manufacturing Co. 141
Continental Foundry and Machine Co. 24, 25
Crane Co. 11
Crouse-Hinds Co. 28, 29
Cutler-Hammer, Inc. ..... Cover 2

D

Dacar Chemical Products Co. 164
De Laval Steam Turbine Co. 114
Dingle-Clark Co., The M-34
Documentation & Licenses, Paris, France M-20
Dravo Corp. 143
Drever Co., The M-20
Dowell, Inc. 108

E

Electric Controller and Manufacturing Co. M-22, M-23
Electric Furnace Co., The 111
Electric Service Manufacturing Co. 155
Electric Storage Battery Co. 6
Elliott Co. 130, 131

F

Falcon Bronze Co. 143
Farrel-Birmingham Co., Inc. 121
Farval Corp. ..... Cover M-4
Fawick Airflex Co. 123
Flinn & Dreffein Engineering Co. M-20
Furnace Engineers, Inc. 122

G

General Electric Co. ..... Cover 4, 8, 9, 34, 117
Gulf Oil Corp. M-26

H

Hagan Corp. 33
Hallden Machine Co., The M-20
Harnischfeger Corp. 22
Heyl & Patterson, Inc. 112
Homestead Valve Manufacturing Co., Inc. M-43
Hyatt Bearings Division, General Motors Corp. M-37
Hyde Park Foundry and Machine Co. 156

I

Industrial Gear Manufacturing Co. 156

J

Johns-Manville Corp. 158
Jones Foundry and Machine Co., W. A. 140

K

Koppers Co., Inc. 18, 19

L

Leeds and Northrup Co. 14
Lewis Foundry and Machine Division, Blaw-Knox Co. 5
Linde Air Products Co., The, Unit of Union Carbide and Carbon Corp. 159
Link-Belt Co. M-38
Lintern Corp. 136
Loftus Engineering Corp. M-24

M

Mackintosh-Hemphill Co. M-31
Magor Car Corp. 164
Manning, Maxwell and Moore, Inc., Shaw-Box Crane and Hoist Division 157
Mathews Conveyer Co. 125
Medart Co., The 126
Mesta Machine Co. ..... Cover 1
John Miles & Partner (London, Ltd.) M-20
Minneapolis-Honeywell Regulator Co. (Industrial Division) 10
Morgan Construction Co. 115
Morgan Engineering Co. 150

N

National Bearing Division, American Brake Shoe Co. 16
National Carbon Division, Union Carbide and Carbon Corp. 134
National Erie Corp. M-40
National Roll & Foundry Co. 2

O

Oakite Products, Inc. 143
Ohio Electric Manufacturing Co., The 118
Okonite Co., The 147

P

Pennsylvania Engineering Corp. M-44
Pennsylvania Transformer Co. 4
Pittsburgh Lectromelt Furnace Corp. 36
Poole Foundry and Machine Co. 7
Post-Glover Electric Co. M-42

R

Reliance Electric and Engineering Co. 142
Ross Carrier Co., The 133
Rust Furnace Co. 105
Rust-Oleum Corp. 21

S

Simonds Abrasive Co. M-30
SKF Industries, Inc. M-28
Smeeth-Harwood Co. 164
Stearns Magnetic Manufacturing Co. 154
Surface Combustion Corp. 12, 13
Swindell-Dressler Corp. 116

T

Taylor Chain Co., S. G. 152
Taylor Sons Co., Chas. 129
Texas Co., The 3
Timken Roller Bearing Co., The M-21
Tool Steel Gear and Pinion Co. M-29
Torrington Manufacturing Co., The 128
Treadwell Construction Co. M-39

U

Union Carbide and Carbon Corp., The Linde Air Products Co., Unit 159
Union Carbide and Carbon Corp., National Carbon Division 134
Union Steel Castings Division, Blaw-Knox Co. 30
United Engineering and Foundry Co. M-35

W

Wagner Electric Corp. 160
Ware Fuse Corp. 129
Wean Engineering Co., Inc., The M-20
Wean Engineering Co. of Canada, Limited, The M-20
Wean Equipment Corp. M-20
Westinghouse Electric Corp. 27, 124, 144, 145
Whitcomb Locomotive Co., The 113
Wilson Engineering Co., Inc., Lee 26

Y

Youngstown Alloy Casting Corp. 17
Youngstown Foundry and Machine Co. 20

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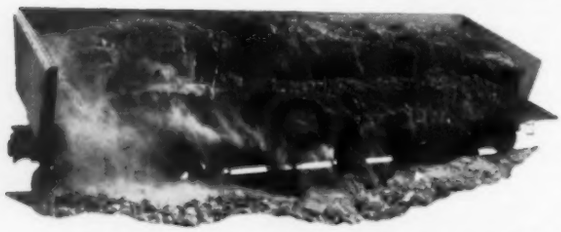

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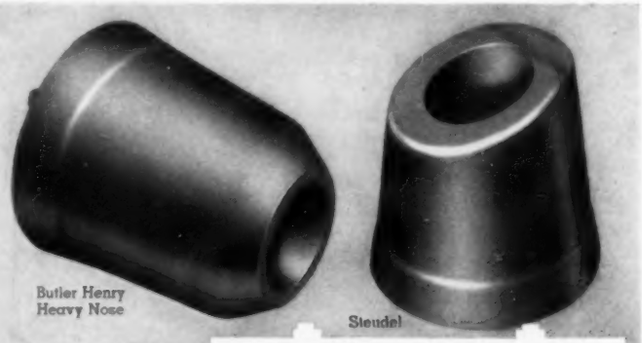

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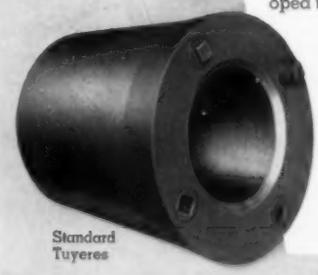

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Above—Exterior view Type ND unit. NU unit (not shown) has slow-speed shaft extending up. At left—Cutaway section to show tapered roller bearings on gear shaft, positive face-type oil seal, unique lubricating pump and oil drain at base of housing.

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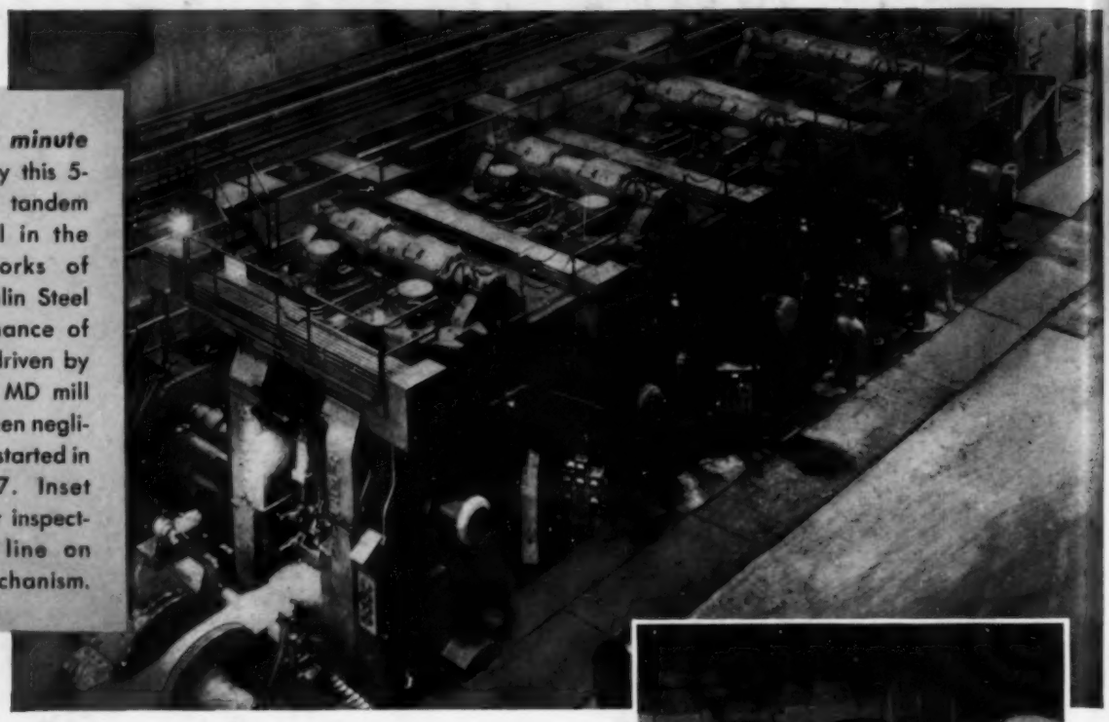

6250 feet per minute is record set by this 5-stand 42-inch tandem cold strip mill in the Aliquippa Works of Jones & Laughlin Steel Corp. Maintenance of screwdowns—driven by 10 G-E 75-hp MD mill motors—has been negligible since mill started in October 1947. Inset shows operator inspecting oil feed line on screwdown mechanism.

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